Encounter '86

An International Rendezvous with Halley's Comet

The first copies of this edition were presented in November 1986 to

His Holiness Pope John Paul II

and

The President of the Republic of Italy, Francesco Cossiga

by

Reimar Lüst
Director General of the European Space Agency

on behalf of the

Inter-Agency Consultative Group
responsible for organising the joint approach to the encounter

Roger-M Bonnet
European Space Agency

Roald Z Sagdeev
Intercosmos

Minoru Oda
Institute of Space and Astronautical Science

Burton I Edelson
National Aeronautics and Space Administration

BR-27
(November 1986)

Encounter '86

An International Rendezvous with Halley's Comet

Cover Painting: '*The Adoration of the Magi*' is a scene in a fresco cycle decorating the interior of the Scrovegni Chapel in Padua. The fresco was painted by the Florentine master Giotto di Bondone, probably in the years 1303 and 1304. Halley's Comet had appeared in 1301, and inspired the artist to depict the Star of Bethlehem as a fiery comet. When the European Space Agency resolved to send a spacecraft to encounter the comet, the story of the fresco painting was recalled, and the spacecraft was named *Giotto* after the artist.

Reproduction of the painting is by courtesy of the Comune di Padova

The initial suggestion to publish this book came from Professor R. Ruffini, President of the International Centre for Relativistic Astrophysics — ICRA — Rome. It was under the auspices of the ICRA that the presentation of the first copies to His Holiness the Pope and President Cossiga were made.

A leather-bound edition of this book limited to 150 copies was published. The first copies of the limited edition were presented to His Holiness Pope John Paul II and Francesco Cossiga, President of the Republic of Italy by Professor Reimar Lüst, Director General of the European Space Agency, on behalf of the Inter-Agency Consultative Group, in November 1986.

Edited and compiled by: Norman Longdon

Protocol and Coordination: Vittorio Manno

Scientific Adviser: Rüdeger Reinhard

Art Editor: Carel Haakman

Published and distributed by: The European Space Agency
Publications Division.

Price Code: E1

Dans son allocution à l'adresse de Sa Sainteté le Pape, le Professeur Lüst explique comment les organismes spatiaux, à travers le Groupe consultatif inter-Agences, ont saisi cette occasion unique du retour de la comète de Halley pour mettre sur pied la plus grande campagne spatiale jamais entreprise à ce jour. Le sens du travail d'équipe, qui se manifeste dans le 'concept de l'Eclaireur', la mise en commun d'idées et de savoir-faire, ainsi que l'esprit de coopération qui continue à se développer, devraient contribuer à promouvoir l'unité et la paix entre les nations.

В своем обращении к его Святейшеству Папе профессор Люст описывает, как космические агентства через посредство Межведомственной консультативной группы использовали уникальнейшую возможность, предоставленную появлением кометы Галлея, для проведения космической кампании, самой большой среди имевших место. Чувство товарищестив, проявившееся в проекте „Лоцман" и при обмене идеями и знаниями, и способ общения, при котором дух сотрудничества оставался и будет оставаться в будущем, превозносятся как позитивный вклад в мирный союз человеческой расы.

法王ポープへの挨拶の中でリュスト教授は、ハレー彗星の回帰がもたらした一生に一度のチャンスを、各宇宙機関がIACGの下に結集して実行した未曽有の宇宙キャンペーンにより如何に見事に活用したかについて述べる。またパスファインダー（軌道決定）計画、アイデアや専門知識の交換、およびこの相互協力の精神がもたらした更に今後も助長されるに違いない共同事業の進め方は、人類の平和的な組織化に明らかに貢献するものであるとして賞賛している。

Presentation Address to His Holiness Pope John Paul II
by Professor Reimar Lüst,
Director General, European Space Agency

Your Holiness,

We bring you today positive proof that science knows no boundaries when it is sought in the name of peace and the furtherance of Man's knowledge of the Universe in which he lives.

For many thousands of years human beings have looked up at the stars, and across the panoply of the heavens they have observed the slow, majestic march of the comets. These wanderers have filled many with dread and foreboding, but at the same time they have stimulated others to think and probe more deeply.

Of all the comets which are visible from the Earth, none is better known than *Halley's Comet* named after the scientist who first plotted its orbit, and correctly predicted its return, and by so doing, gave fresh impetus to the study of comets and their place in the solar system. The regular visits of this comet have been observed since 240 BC, and they have coincided with many of the dramatic events of history. Artists have portrayed the comet: in particular the apparition of 1301 inspired Giotto di Bondone to include the comet as the Star of Bethlehem in his fresco *The Adoration of the Magi* which adorns La Cappella degli Scrovegni in Padua.

It was therefore fitting that Halley's Comet, approaching the Sun once more on its seventy-six year journey, should be chosen for the first joint venture by the four space agencies to learn more of the nature and composition of this ancient traveller.

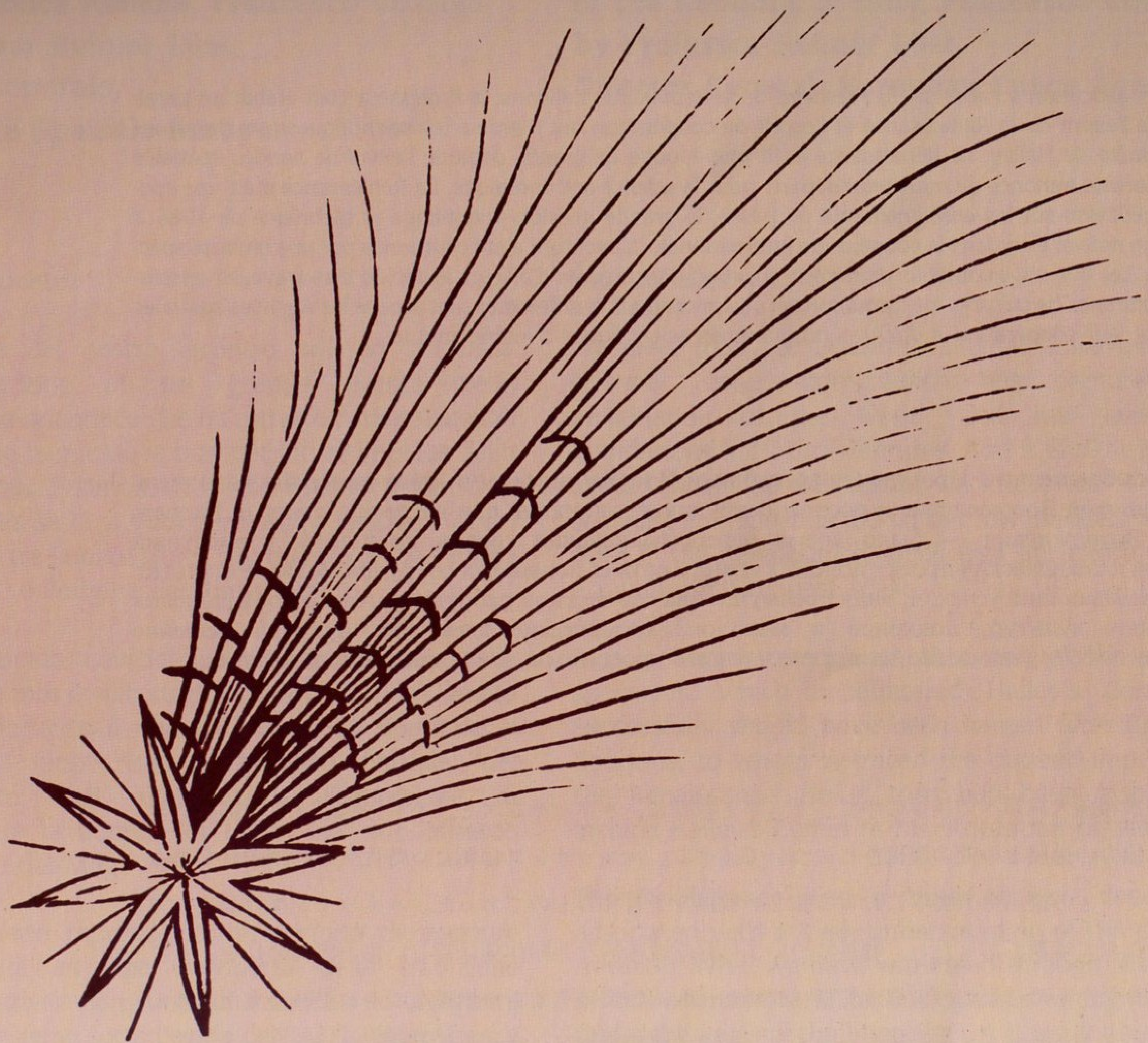
From the inception of the venture, the space agencies, and the international space science community strove together to ensure that this once-in-a-lifetime opportunity would not fail for lack of mutual trust and endeavour. The result was the largest space campaign ever undertaken.

Through the Inter-Agency Consultative Group, the scientists opened not only their doors, but also their minds and aspirations, and their expertise to each other. Thus was the fleet of spacecraft, which carried the instruments and hopes of Halley's successors, and the ground stations which guided and monitored them, prepared for the eventful encounter with the comet in the Spring of 1986. The American ICE spacecraft although passing at a very great distance, observed particles originating from the Halley Comet nucleus; the Japanese Sakigake and Suisei spacecraft passed closer, probing the outer layers of Halley's atmosphere, while the two Soviet Vega spacecraft would fly by even closer, penetrating deeply into the atmosphere. The European Space Agency's Giotto spacecraft was set to achieve the closest possible approach to the nucleus of the comet. Yet the precise position of the nucleus within the far-scattered coma visible from the Earth was not known.

It was then that the sense of partnership manifested itself most strongly. The technologists came together to present the Pathfinder Concept by which the Russian Vega spacecraft would relay the latest information they had on the comet nucleus through the ground stations so that Giotto could be guided on its final approach. But this information, in itself, would not be sufficient unless the exact location of the Vega craft were known. The United States offered its Deep Space Network to provide the delicate accuracy required to complete the answer. The effectiveness of this internationally inspired collaboration was witnessed across the world as the television screens recorded the exciting last moments of the encounter. We have seen for the first time, the nucleus of Halley's Comet, the fount of all the activity which provides such a spectacular display during its closest passage to the sun.

During the succeeding months the cooperative spirit has remained as scientific data has been exchanged and analysed, and the comet has given up many of its secrets. And the recent conference in Heidelberg on the exploration of Halley's Comet brought together scientists from all continents and space missions to exchange their discoveries. Man's knowledge of the origin of the solar system has edged a little further forward, and the way is open for fresh explorations.

Of equal importance has been the joint nature of the venture. I am, therefore, delighted to announce that the Inter-Agency Consultative Group will remain in being, bringing together scientists and technologists from many races and creeds to explore the Universe around us. We all applaud the growth of belief in a common fellowship born of the quest for knowledge by which Man can unshackle the chains of ignorance, and step confidently into the future in peaceful union.



Halley's Comet as shown in the Nürnberg Chronicle, 684 AD.

Dans son allocution à l'adresse du Président de la République Italienne, le Professeur Lüst établit un parallèle entre l'esprit de la Renaissance et l'esprit de coopération qui a animé les scientifiques lors du retour de la comète de Halley. La Renaissance était une époque de grands départs; l'envoi de sondes spatiales vers la comète annonce de nouveaux départs pour la science astronomique. La Renaissance était une époque de réflexion sur les enseignements du passé; la grande mission scientifique et technique de 1986 a suscité un nouvel élan dans la coopération internationale. L'aventure a été couronnée par une réussite spectaculaire. Les avantages obtenus dans cette collaboration, comme d'ailleurs le défi de faire travailler ensemble des hommes de cultures, de formations et de conceptions si différentes, ont amené les Agences spatiales à étendre leur coopération à d'autres programmes scientifiques d'intérêt mutuel.

В своем обращении к Президенту республики Италия профессор Люст проводит параллель между эпохой Возраждения и ростом сотрудничества наций при встрече с кометой Галлея. Эпоха Возрождения — было время переосмысливания уроков прошлого; совместный научный и технический проект полета к комете разжег новый дух сотрудничества. Результат — захватывающий успех, и, видя преимущества совместной работы, выгоду от объединения различных культур, подходов и методов, космические агентства приняли решение расширить сотрудничество на другие научные программы, имеющие общий интерес.

イタリヤ共和国大統領への挨拶の中で、リュスト教授は、ルネッサンスと、ハレー彗星との遭遇時における国際協力の進展との間の類似性にについて述べる。ルネッサンスは新しい時代への門出の時であったし、ハレーとの遭遇は天文学における新しい展開を予告するものであった。ルネッサンスは過去の教条を考えなおす時期であったし、彗星についての科学技術的な共同作業は新しい協力精神の灯をともすものであった。その結果この事業は見事に成功し、共同作業の有効さや相異なるそれぞれの文化、考え方や技術がうまく融合しあった状況を知って、各宇宙機関は相互に関心のある他の科学プログラムにまで国際協力を拡張しようと決心した。

Discorso Inaugurale al Signor Presidente della Republica Italiana, Francesco Cossiga del Professor Reimar Lüst, Direttore Generale dell'Agenzia Spaziale Europea

Signor Presidente,

Il significato del nostro incontro odierno sta nella commemorazione di un grande evento nella cooperazione scientifica che ha attratto l'attenzione del mondo, e che ha messo le basi per future imprese dello stesso genere. È sintomatico che questo incontro si tenga in Italia se ci si vuol permettere l'audacia di un parallelismo tra i nostri sforzi, per quanto di gran lunga più modesti, e l'origine del Rinascimento.

È una fortunata coincidenza che una sonda della flottiglia che mosse allo storico incontro con la Cometa di Halley, portasse il nome di Giotto di Bondone al quale può farsi risalire l'impulso iniziale del Rinascimento. Egli infatti ebbe l'ispirazione di rappresentare la Cometa di Halley nel suo affresco l'Adorazione dei Magi.

Il Rinascimento rappresentò un periodo di aperture novelle unite ad una riscoperta della tradizione classica. L'attività congiunta di scienziati ed ingegneri, lavorando insieme sotto l'egida dell'IACG, l'InterAgency Consultative Group, ci ha testimoniato di un nuovo slancio in astronomia, una delle più antiche discipline

---

Presentation Address to His Excellency The President of the Republic of Italy, Francesco Cossiga, by Professor Reimar Lüst, Director General, European Space Agency

Your Excellency,

We meet today to celebrate a great achievement in scientific cooperation which has captured the imagination of the world, and has laid solid foundations for future ventures. And it is right that we should hold the celebration in Italy, for it is not straining comparisons too far to draw parallels with the birth of the Renaissance, albeit that our efforts are on a much more modest scale.

It is a happy coincidence that one of the fleet of spacecraft which encountered Halley's Comet so successfully should have been named after Giotto di Bondone, to whom is traced the original impetus for the Renaissance. He in turn had been inspired to include Halley's Comet in his 'Adoration of the Magi'.

The Renaissance was a time of new departures, associated with a fresh understanding of the classical tradition. What we have witnessed through the efforts of the scientists and technologists working together under the aegis of the Inter-Agency Consultative Group has been a new departure in astronomy, one of the oldest and most traditional of sciences. The results of

scientifiche. Il risultato dei loro sforzi congiunti ha condotto a delle osservazioni rivoluzionarie sulla natura delle Comete, sui fossili cioè della nebulosa da cui trasse origine il sistema solare.

Il Rinascimento si diffuse dall'Italia attraverso la più gran parte dell'Europa. Forse in questo rispetto possiamo persino prevalerci di qualche vantaggio. L'IACG infatti ha vocazione globale in quanto le quattro Agenzie che ne fanno parte rappresentano più di venti nazioni.

Il Rinascimento fu un periodo di movimento delle spirito umano e di ripensamento delle grandi lezioni del passato. Noi concepiamo i nostri sforzi nella stessa luce. Lo spirito di cooperazione, sostenuto cos entusiasticamente dal Prof. Giuseppe Colombo, al momento della prima riunione dell'IACG a Padova nel 1981, ha brillato fulgidamente negli anni successivi. Infatti il coordinamento di tanti disparati esperimenti scientifici per migliorarne il rendimento, lo scambio di informazioni tecniche e l'omogeneizzazione di sistemi e scale dei tempi differenti e separati in una pianificazione congiunta, pur nel rispetto delle procedure proprie di ogni Agenzia, ha richiesto pazienza,

their labours has been a revolutionary new understanding of the nature of comets; those primordial remnants of the nebula from which the solar system originated.

The Renaissance spread from Italy to affect much of the rest of Europe. Perhaps this is the one respect in which we can make greater claims, for the Inter-Agency Consultative Group is truly global, as the four agencies taking part represent more than twenty nations.

The Renaissance was a time of movement of the human spirit, a rethinking of the lessons of the past. We see our efforts in a similar light. The spirit of cooperation kindled so enthusiastically by Professor Giuseppe Colombo when the Inter-Agency Consultative Group first met in Padua in September 1981 has burned brightly throughout the succeeding years.

To coordinate the scientific experiments to ensure the best possible data return, to exchange technical information and link widely dispersed systems and schedules into a common programme while leaving individual freedom for each Agency to develop its projects to conform with its own methods and means tatto e comprensione ma soprattutto fiducia reciproca e buona volontà.

Il risultato fu all'altezza delle aspettative, ed evidente a tutti mentre i dati delle sonde riempivano gli schermi televisivi in tutto il mondo e i computers degli scienziati.

Nelle Agenzie spaziali abbiamo fatto un'analisi dettagliata dei nostri progressi e li abbiamo messi in prospettiva. Abbiamo apprezzato il vantaggio di lavorare congiuntamente, di porre in contatto culture, metodi e tecniche differenti, per ottenere per noi tutti un beneficio maggiore di quanto non sia ottenibile indipendentemente da ogni singola Agenzia.

Sono lieto di conseguenza di poter annunciare che oggi non solo commemoriamo un'impresa condotta a buon fine, ma anche la decisione di continuare la nostra cooperazione, e di estenderla negli anni a venire ad altri programmi di interesse reciproco.

Il Rinascimento si sviluppò da modesti inizi in un illuminamento generale. Esprimiamo oggi l'augurio che tramite la cooperazione per l'incontro della Cometa di

has called for patience, tact, understanding, and above all trust and goodwill.

The outcome was there for all to see as the data flowed onto the television screens around the world as well as into the computers of the scientists.

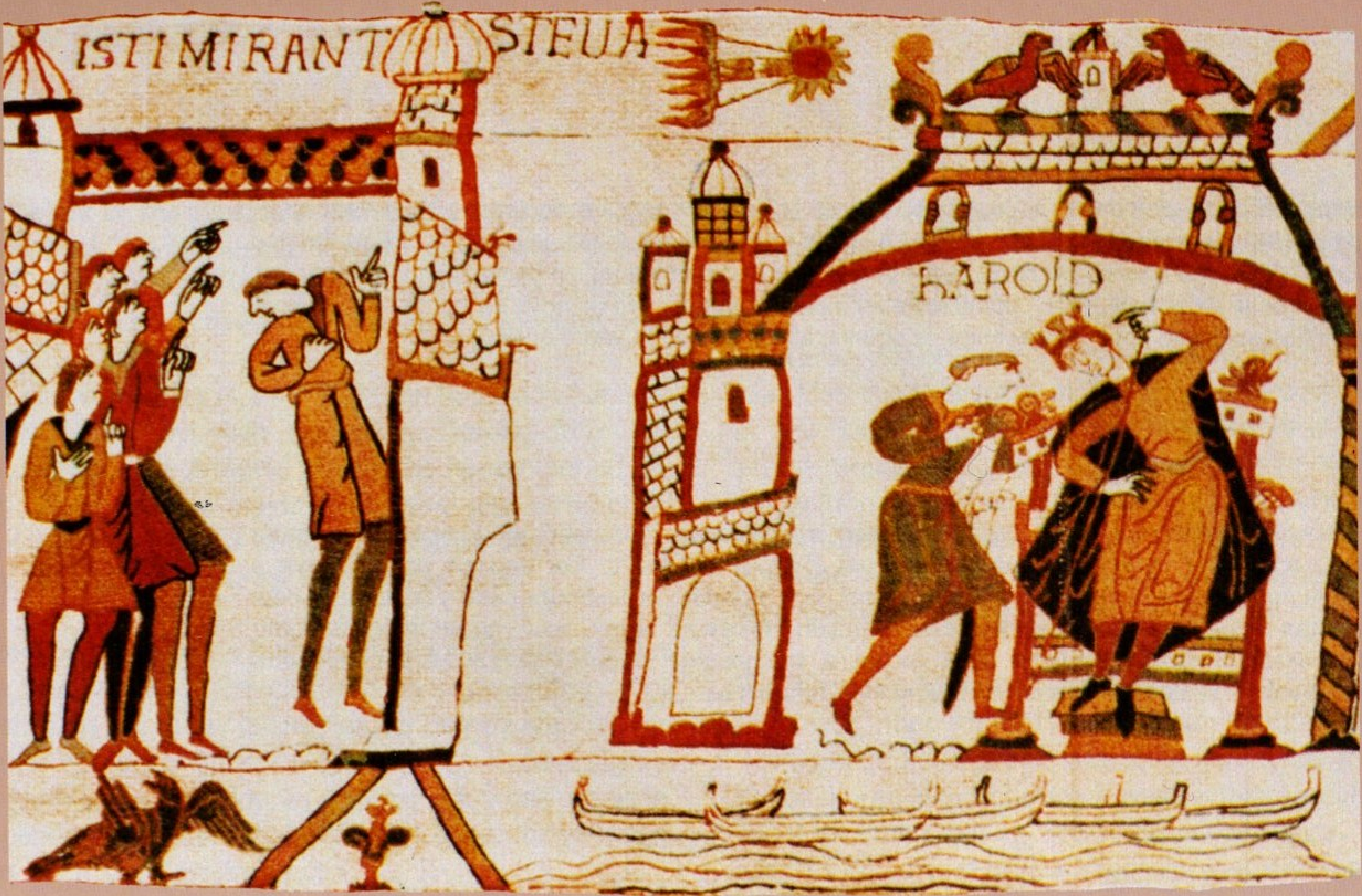
We, in the Space Agencies, have now had time to review our achievements and to put them into perspective. What we see are the advantages of working together, the challenges of melding different cultures, different approaches and different techniques, so that we may all benefit beyond the scope available to any one agency.

I am therefore pleased to report that not only are we celebrating an endeavour successfully completed, but also the decision to continue our close cooperation; extending it in the coming years to other scientific programmes of mutual interest.

The Renaissance grew from small beginnings to a general enlightenment. Let us hope that the space scientists and technologists have by their cooperation during the many phases associated with the encounter

Halley siano stati impiantati dagli scienziati e ingegneri spaziali quei semi forieri nelle decadi future di lunga e benefica cooperazione basata sulla fiducia e sullo sforzo congiunto.

with Halley's Comet planted the seeds which could blossom in the coming decades into a long and fruitful cooperation based on trust and the sharing of effort.



From the Bayeux Tapestry — depicting 1066 apperation.

Dans cette allocution de bienvenue prononcée lors de la première réunion du Groupe consultatif inter-Agences en 1981, le regretté Professeur Colombo, après avoir souligné le rôle joué par la cité de Padoue dans la naissance de la science moderne, forme le voeu que les scientifiques, en unissant leurs efforts pour l'exploration de la comète de Halley, montreront au monde comment des hommes de bonne volonté peuvent travailler ensemble pour faire avancer la science au service de la vérité et de la paix.

Это приветственное выступление покойного профессора Коломбо на первом заседании Межведомственной консультативной группы (IACG) в 1981 г. Он описал роль Падуи в рождении современной науки и предположил, что ученые, объединив свои усилия для осуществления проектов изучения кометы Галлея, покажут миру, как люди доброй воли, работая вместе, смогут внести свой вклад в увеличение знаний, установления истин и способствовать созданию мирного и лучшего общества.

この文章は1981年IACGの第1回の会議の際、故コロンボ教授によって行われた歓迎講演の内容である。彼は現代科学の誕生に果したパドゥアの役割りについて述べた。また科学者がハレー彗星ミッションの方向づけに協力することにより、人類の善意の努力がいかに知識を拡大し、真理を確立し、平和で善い社会を作るものかを世界へ示すことになるのであると説いている。

Welcoming Address to the first Inter-Agency Consultative Group meeting
Padova, 13-15 September 1981

by the late Professor Giuseppe Colombo

On behalf of the President and of the Academic Community of the University, I wish to welcome you to Padova. I also wish to express our feeling of gratitude to ESA for having convened this historic meeting here.

The city of Padova is a very old pre-Roman settlement on rich soil, between the rivers flowing from the Dolomites to the Adriatic. During the Roman period the city flourished as a major agricultural and commercial centre. Invasions and natural calamities destroyed the city several times during the middle ages.

After the Longobards had razed Padova to the ground, the population of the city and its surroundings took shelter on the many islands of the nearby lagoon, and Venice was born. Almost a century later Padova started to grow again, reaching its greatest splendour as an independent and free community in the thirteenth century with the Carrara family.

In the year 1300 a rich family of usurers, the Scrovegni family bought the land on which the Roman arena stood and its surroundings and there built the family chapel. Giotto di Bondone was asked to paint the fresco, the monumental masterpiece you have admired today. In 1301 Halley's Comet revisited the inner solar system, and one or two years later Giotto began his work.

The University of Padova, established in 1222, only one year after the University of Bologna, developed steadily in the following century, reaching its zenith when Venice took over political control of the city. Venice, in recognition of the strong link with its mother city, made the University of Padova an island of freedom, a shelter from the inquisition, a unique 'studium' whose motto was 'Universa Universis Patavina Libertas.'

The Venetian Republic established several basic rules. One was that the Studium Patavinum, the only 'studium' of the Republic, was to be independent of any political or religious control. It was therefore established in Padova and not in Venice. The theological school which formed part of the studium was separate from the University. The Jesuits, who were controlling most, if not all, of the universities in Europe at that time, did not control Padova. Degrees were conferred in the name of the Venetian Republic and not in the name of the Pope, and a profession of faith was not required to study here.

From the University of Padova the European Medical School developed. For more than a century, only in this school did the professors teach in the aisles of the hospital and only here did they teach anatomy by sectioning human bodies in the Anatomic Theatre, which you will have the opportunity to visit tomorrow.

Galileo came to Padova 500 years ago at the end of the sixteenth century and was here for 20 years. From here he observed the four major satellites of Jupiter and showed beyond doubt that the centre of the Universe was not the Earth but the Sun.

Silently and smoothly, just as the gondolas glide through Venice, the modern scientific revolution flourished in Padova, the revolution that brought society from the medieval to the modern age.

The significance of the meeting that will take place over the next two days may go far beyond the scientific and technological interest of the matter with which you will be dealing. The discussions on the scientific experiments and technological problems of the various missions to Halley's Comet, as well as the setting up of an efficient worldwide organisation for coordination of the efforts, will play an essential role in maximising the chances of success for such a difficult endeavour. If you can succeed in reaching agreement on optimum integration of the various space probes and the ground and space observations beyond national interests and within the bounds of a fruitful cooperation, you can show the World how men of good will have an intrinsic ability to work together to establish the truth, to increase knowledge among men, and to foster a peaceful and better society.

For the very reason that space has no boundaries, Man in his space ventures will be confronted sooner or later with the choice between war, which would probably lead to the final destruction of our civilisation, and cooperation. In the popular tradition, the apparition of a comet has often been considered a precursory sign of calamity, famine, natural disaster or war. Let us try to disprove this belief. Let us try to profit from the unique occasion of the first perihelion passage of Halley's Comet in the space age to promote worldwide peaceful cooperation in space.

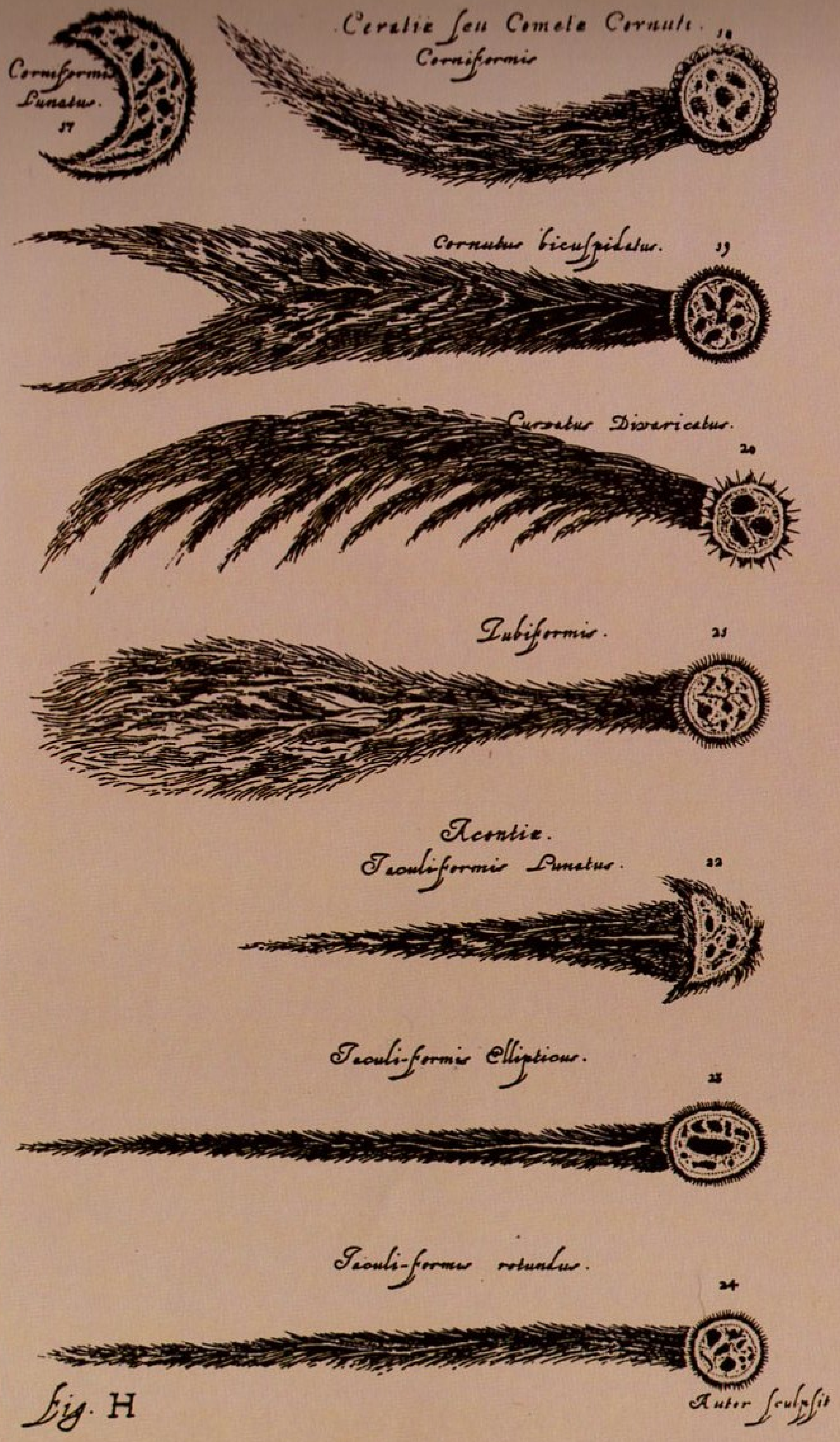


Fig. H

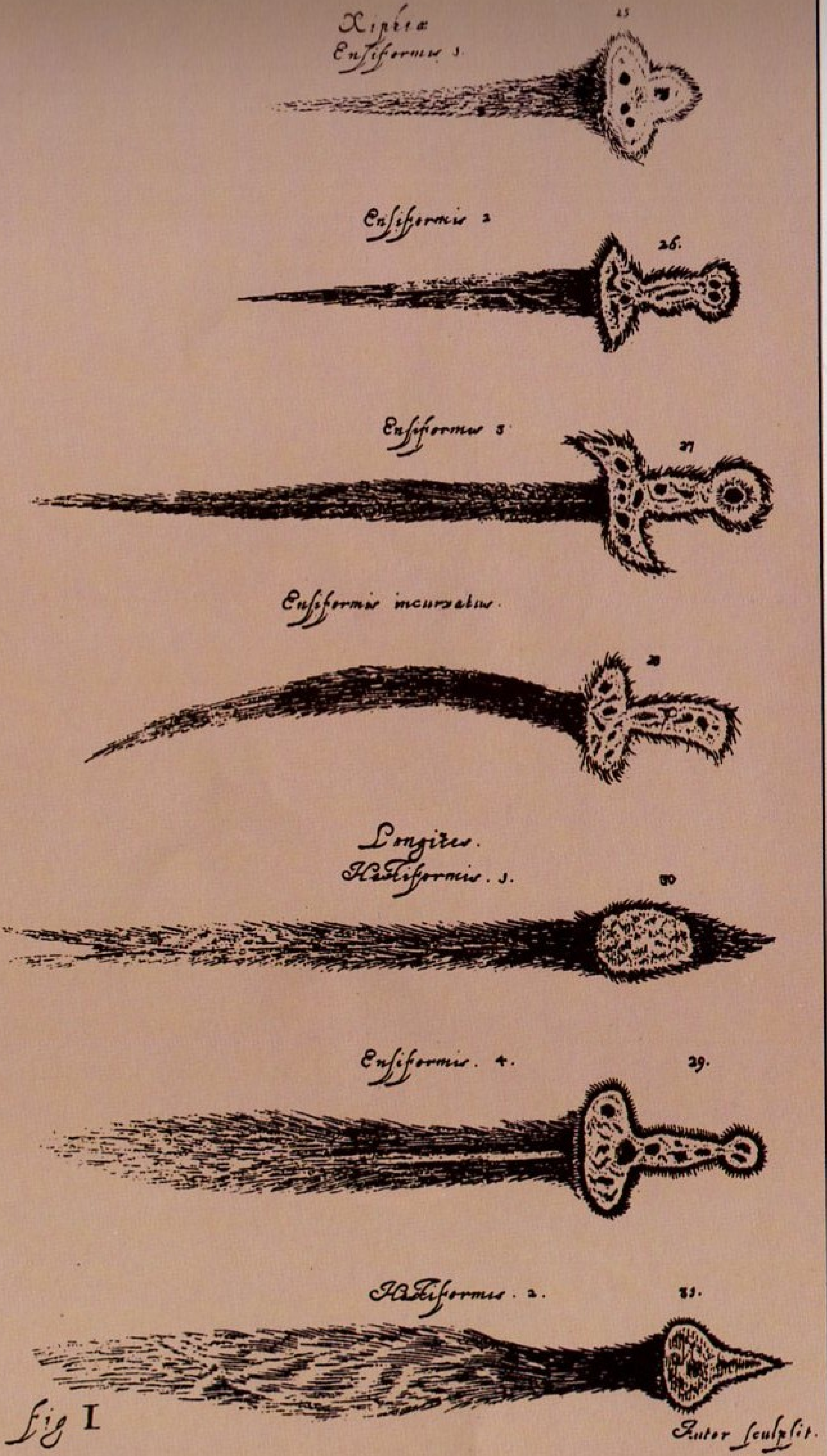
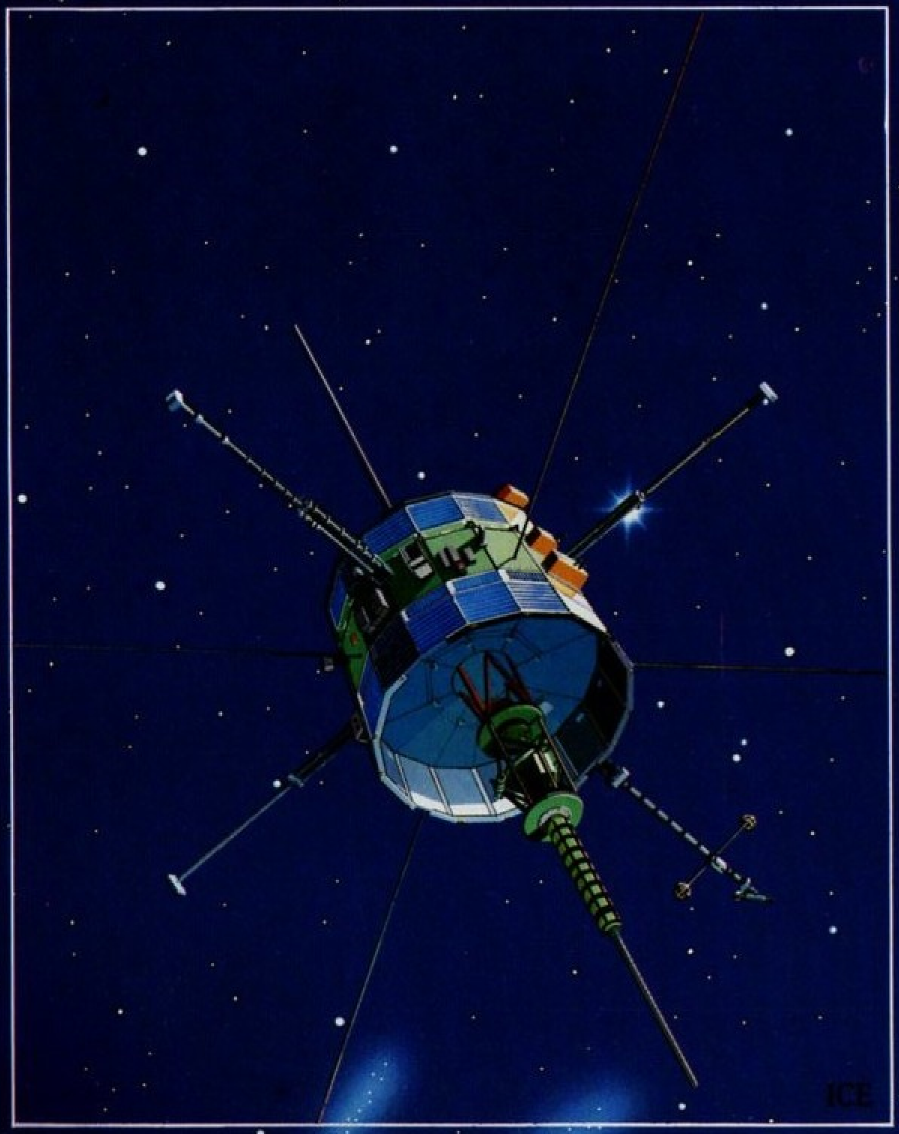
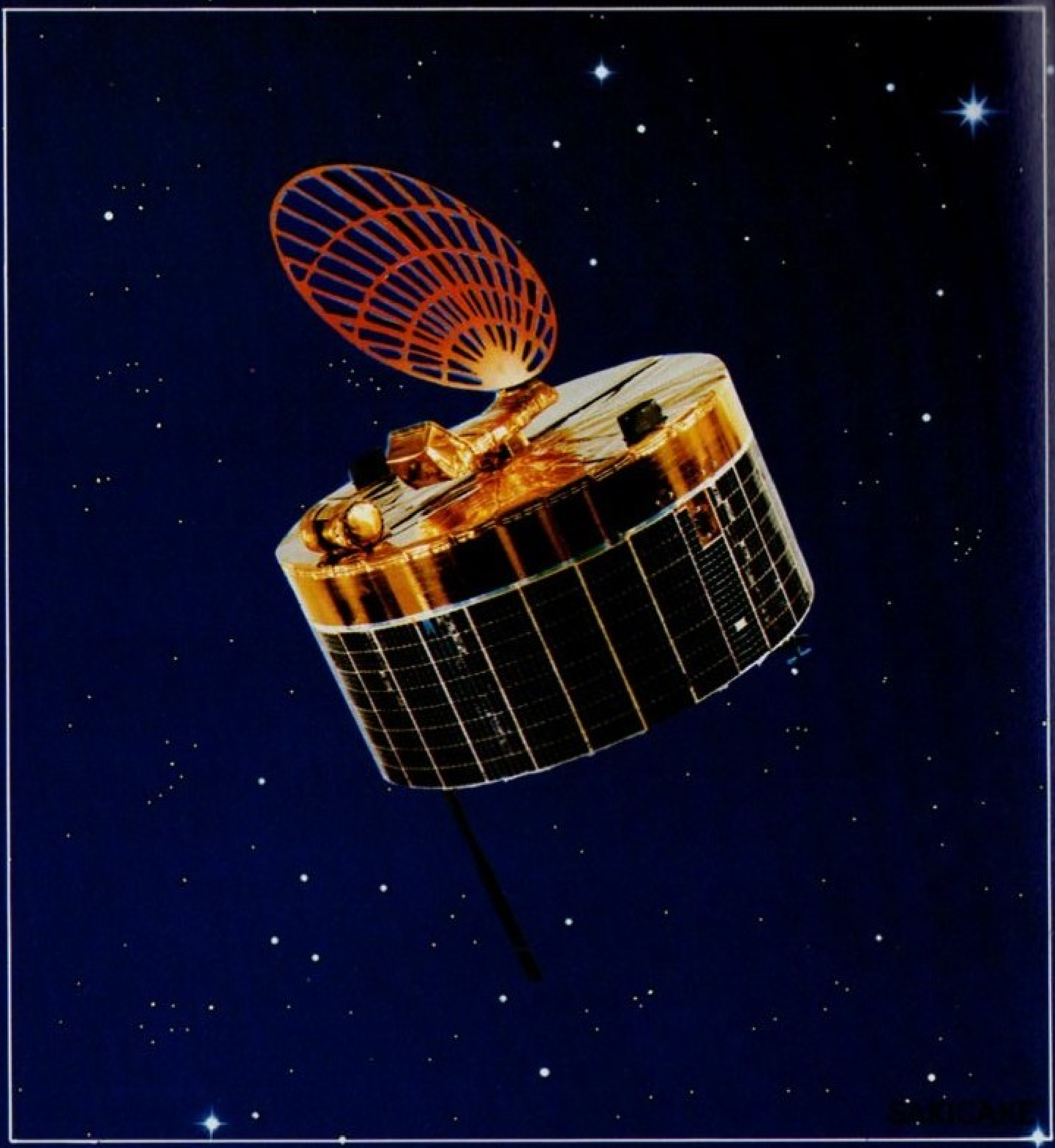
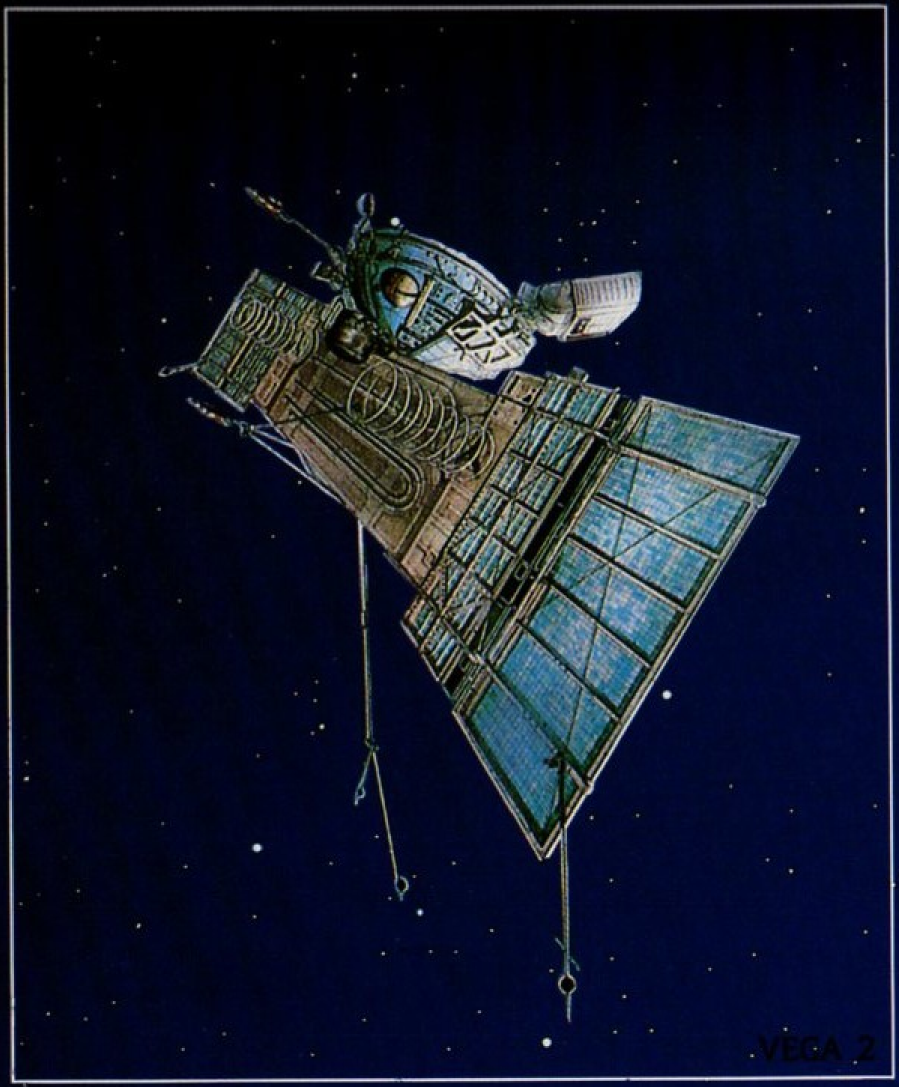


Fig I

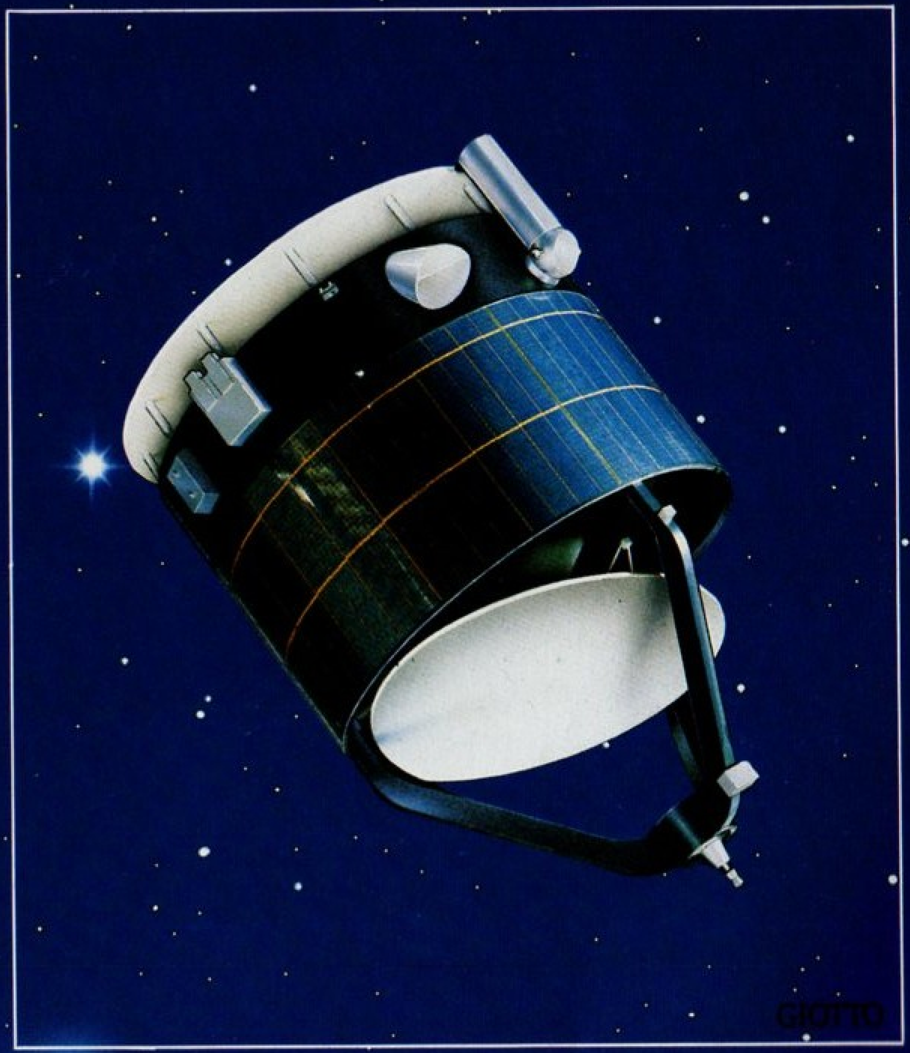
A selection from Johann Hevelius' classification of comet tails in the seventeenth century.


ICE


SAKIGAKE



VEGA 2



GIOTTO

Agence spatiale européenne (ESA)

Composition colorée du noyau de la comète de Halley à partir de quatre photos prises par la caméra multibande (HMC) à bord de Giotto, respectivement à des distances de 19 947, 9847, 4947 et 2490 km du noyau. Lors de la phase d'approche finale, la résolution spatiale devenait de plus en plus fine à mesure que la distance diminuait (100 m de résolution dans l'image du centre). En même temps l'image se rapetissait en raison de la fixité du champ de vue de la caméra (0,1°). L'image du centre mesure 4 km de côté. Les vues étaient prises avec un filtre transparent couvrant la gamme de longueur d'onde 300 – 1000 nm. Le Soleil est à gauche, à 27° au-dessus de l'horizontale et 15° à l'arrière du plan de l'image. On distingue le côté nuit du noyau (partie sombre à droite), les jets de poussière brillants du côté jour (à gauche), et la faible lueur de la chevelure de poussière dans le fond. Le côté du noyau exposé à la lumière du jour (en haut à gauche) montre plusieurs structures cratériformes. (Photos MPAe Lindau, 1986).

Европейское Космическое Агентство (ESA)

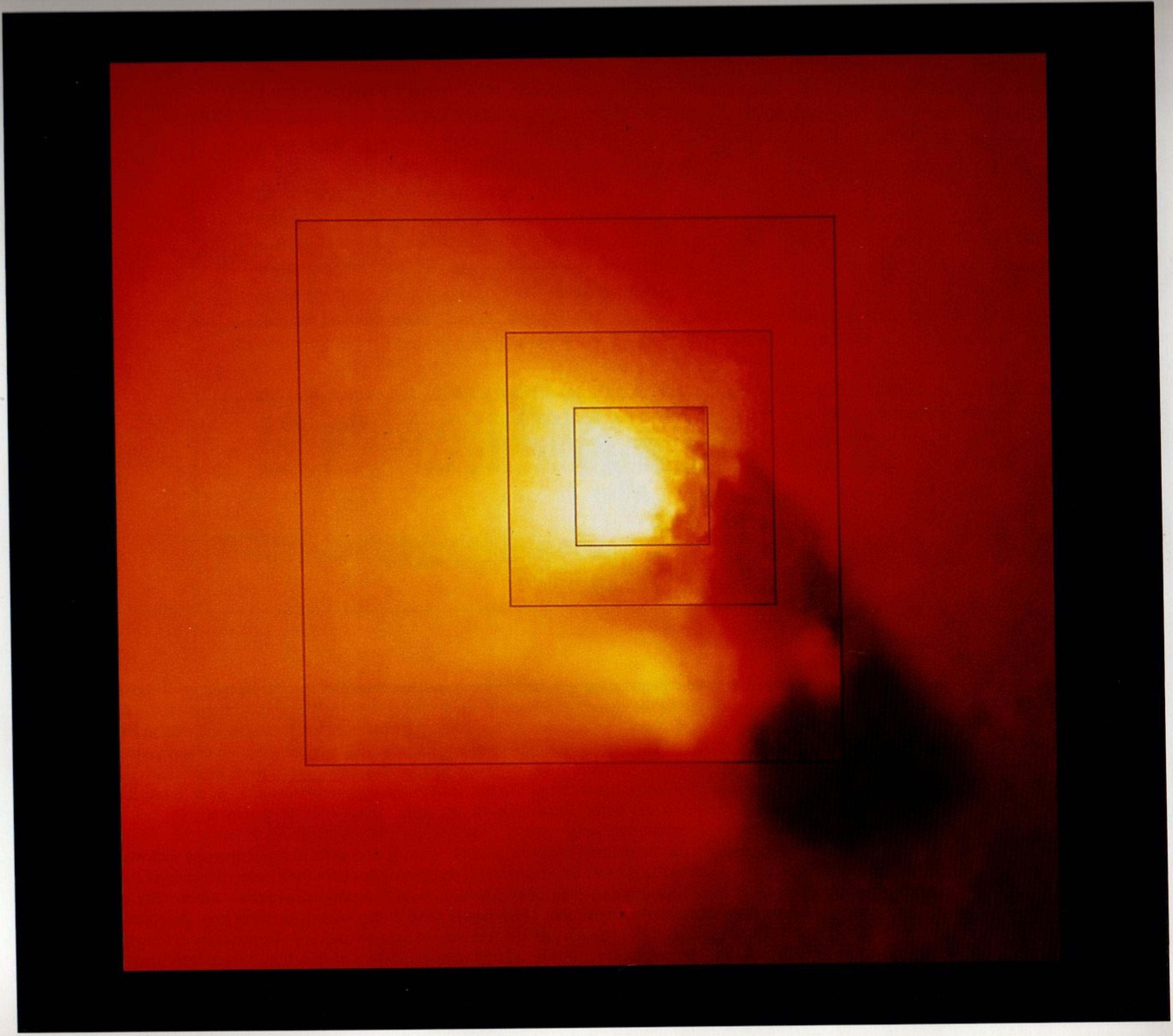
Псевдоцветное совмещенное изображение ядра кометы Галлея. Изображение составлено из четырех снимков, полученных с помощью спектрозональной ТВ-камеры Галлей (HMC) на борту космического аппарата ДЖОТТО на 19947, 9847 и 4947, 2490 км от ядра. На конечной стадии подлета ядро разрешалось и по мере приближения к нему получали изображения с все более высоким пространственным разрешением (100 м для кадра, полученного с минимального расстояния). В то же время размер кадра уменьшался из-за фиксированного поля зрения камеры (0,1°). Кадр, полученный с минимального расстояния от ядра, соответствует 4 километрам. Снимки получались в диапазоне длин волн 300-1000 км (без спектрозонального фильтра). Солнце находится слева, 27° над горизонталью снимка и 15° за плоскостью снимка. На совмещенном изображении видна темная ночная сторона ядра (справа), яркие джеты пыли на дневной стороне (слева) и слабый фоновый свет пылевой комы. Можно различить несколько кратероподобных образований на освещенной дневной стороне (вверху слева) (Право на копирование 1986 MPAe Линдау).

ヨーロッパ宇宙機構（ESA）

ハレー彗星の核の擬似カラー合成写真。この写真はジョットに搭載されたハレー多色カメラ（HMC）により、核から19947、9847、4947、2490kmの所で撮られた4枚の画像を合成したものである。接近の最終段階では、核を識別することが可能となり、核に近づくにつれ空間分解能はますます向上した。（最も核に近づいた時のフレームでは 50m）。同時にフレームのスケールはカメラの固定された視野角（0.1°）のためにますます減少した。一番内側のフレームでは4kmに相当する。この画像はフィルターなしのモード（波長域300～1000nmに感ずる）で撮影された。太陽の方向は水平線上左方27°、紙面の後方15°の方向にある。合成写真は核の暗い夜側（右）、昼側の明るいダスト・ジェット（左）、ダストコマの淡い背光等を写し出している。核の昼側（左上方）には数個のクレーター状の模様の存在が見てとれる。（画像版権。1986年、MPAe Lindau）

European Space Agency (ESA)

Pseudocolour composite image of the nucleus of Halley's Comet. The picture is a composite of four images taken by the Halley Multicolour Camera (HMC) on board Giotto at 19947, 9847, 4947 and 2490 km from the nucleus. In the final approach phase the nucleus was resolved and images with higher and higher spatial resolution (50 m per pixel in the innermost frame) were taken as the distance to the nucleus decreased. At the same time the size of the frame decreased due to the fixed field of view of the camera (0.1°). The innermost frame corresponds to four kilometres. The images were exposed through the clear filter covering the wavelength range 300 - 1000 nm. The direction of the Sun is to the left, 27° above the horizontal, and 15° behind the image plane. The composite image shows the dark night side of the nucleus (right), the bright dust jets on the day side (left), and the faint background light of the dust coma. On the daylight side of the nucleus several crater-like features can be identified in the innermost two frames. (image copyright 1986 MPAe Lindau)



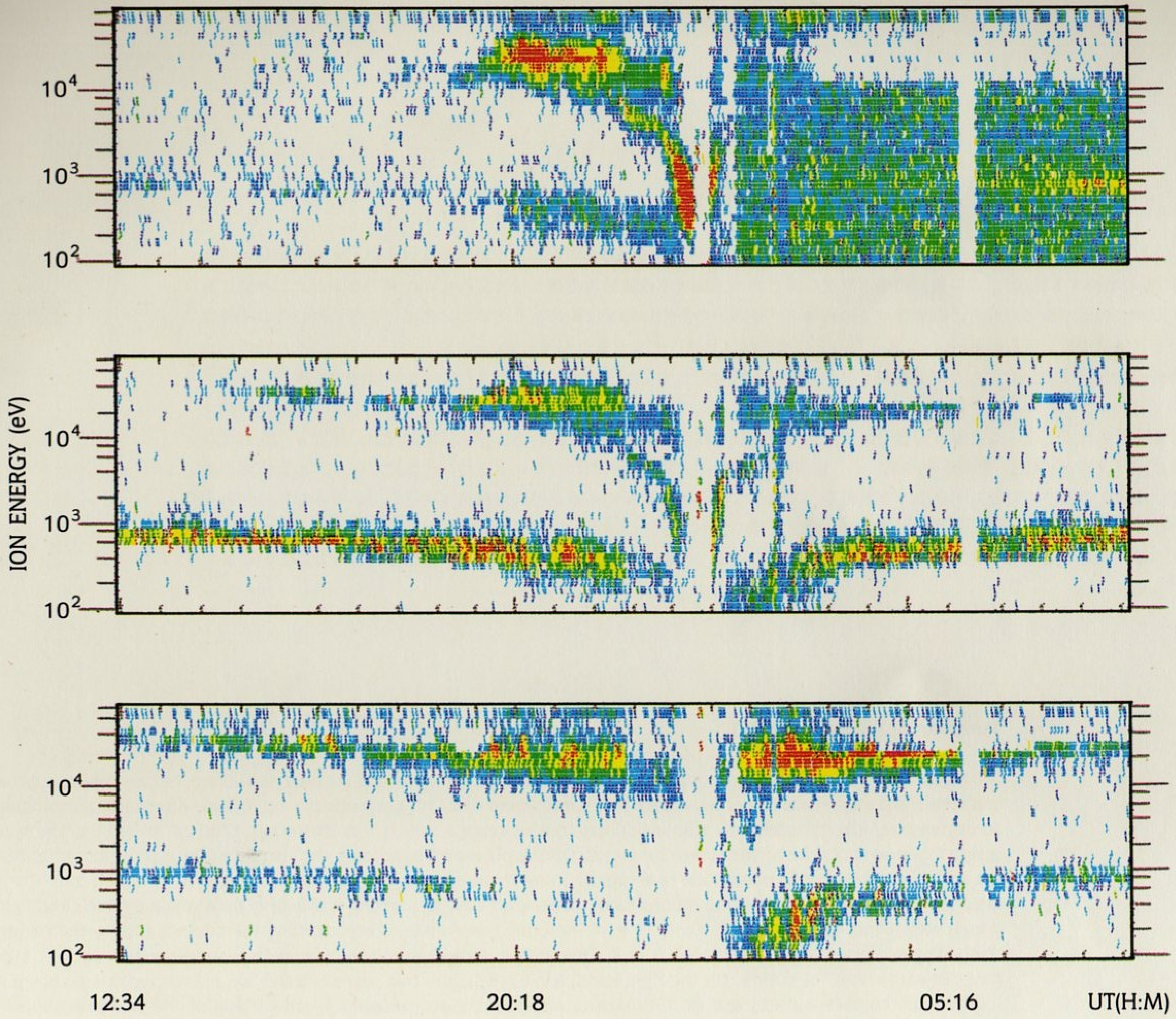
ヨーロッパ宇宙機構（ESA）

3つの異なる方向で観測された彗星イオン。ジョット搭載のジョンストン型プラズマ分析実験（JPA）を構成する検出器のうちの1つ、捕捉イオン（太陽風に取り込まれた彗星イオン）検出器により測られた。上のパネルは85°～95°、即ち探査機スピン軸に垂直方向を、中央のパネルは50°～60°、即ち太陽風方向を、下のパネルは15°～25°、即ち探査機の進行方向におけるものである。観測結果は3月13日12:34時UT（最近接前280万km）より、3月14日12:00UT（最近接後290万km）迄のものである。縦軸はeV単位でのイオンのエネルギーを表わし、色は強度を示す（赤が最大の、暗い青が最小のフラックスを表わす）。最大の強度を持つエネルギーはプラズマの速度を与え、分布の幅がプラズマの温度を与える。個々のパネルにおいて、下部はプロトンに、上部は質量数12～22の範囲（大部分はO^+、OH^+、H_2O^+）のイオンに関するものである。核から遠いところでは乱されていない太陽風の存在が中央のパネルの約700eV（350km/sに対応）の所に見てとれる。核に近くなると分布は広がり（プラズマ加熱）低いエネルギー域に移って行くが、これは太陽風の減速を意味している。核に非常に近くなると太陽風は曲げられて中央パネルのカバーする角度域からはそれてしまう。一方、上のパネルは水分子族イオンが核から相当遠いところで既に（太陽風磁場に）捕捉されていることを示している。このことは約30keVのエネルギーの所にあらわれている。これらのイオンには太陽風イオンであるとしたときのエネルギーの4倍ものエネルギーに達しているものさえある。

エネルギー分布は19.30時UTから20.00時UTの間で相当に広がるが、このことはジョットが衝撃波面を横切ったことを示す。核から遠い所では、捕捉イオンは大部分探査機のスピン軸に垂直な方向に於いて観測されたが、この時点の磁場方向もまた探査機スピン軸に対し大体直角方向にあった。核に近づくにつれて捕捉イオンは前方からやってきて（下のパネル）いるが、これは磁力線が彗星の周縁部を巻いて流れていることを示している。各パネルの中央部にある空白部は最接近時におけるダスト衝撃に原因する、ジョットとの通信途絶のために生じたデータ欠除である。

European Space Agency (ESA)

Cometary ions observed in three different directions by the Implanted Ion Sensor of the JPA experiment on board Giotto. Upper panel: 85° - 95°, i.e. perpendicular to the spacecraft spin axis; middle panel: 50° - 60°, i.e.in the direction of the solar wind; lower panel: 15° - 25°, i.e. in the forward direction. Observations are shown from 12.34 UT on 13 March (2.8 million km. before closest approach) to 12.00 UT on 14 March (2.9 million km. after closest approach). The ordinate gives ion energy in electron Volts (eV), colour coding represents intensity with red corresponding to the highest, and dark blue to the lowest fluxes. The energy of the peak intensity gives the plasma velocity, the width of the distribution the plasma temperature. In each panel the lower band refers to protons, the upper panel to ions in the mass range 12 - 22 atomic mass units (predominantly O^+, OH^+, H_2O^+). At large distances from the nucleus the undisturbed solar wind is clearly seen in the middle panel at about 700 eV, corresponding to 350 km/s. Closer to the nucleus the distribution broadens (plasma heating) and shifts to lower energies, indicating the deceleration of the solar wind. Very close to the nucleus the solar wind is deflected away from the viewing direction of the middle sensor. The upper panel shows cometary water group pick-up ions already at large distances from the nucleus. They are identified by their energy (about 30 keV) which can be up to four times higher than if they were solar wind ions. Their distribution widens significantly between 19.30 and 20.00 UT indicating Giotto's crossing of the bow shock. At large distances from the nucleus pick-up ions were mostly observed perpendicular to the spacecraft spin axis which at that time was roughly perpendicular to the magnetic field. Closer to the nucleus most pick-up ions come from a forward direction (lower panel) indicating the draping of the magnetic field lines around the comet. The blank spaces in the centre of each panel are data gaps due to the loss of the Giotto telemetry link after dust impact at the time of closest approach.



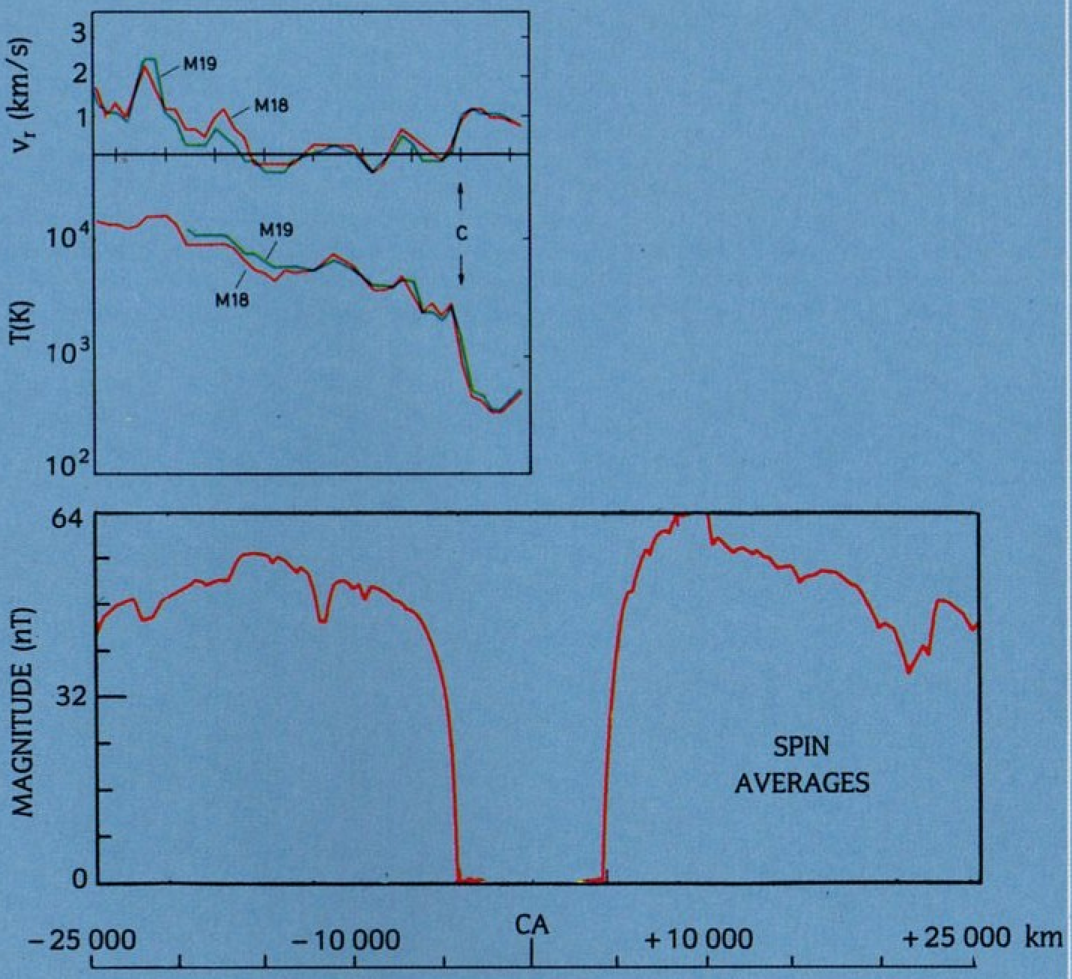
ION ENERGY (eV)
10⁴
10³
10²
10⁴
10³
10²
10⁴
10³
10²
12:34
20:18
05:16
UT(H:M)

ヨーロッパ宇宙機構（ESA）

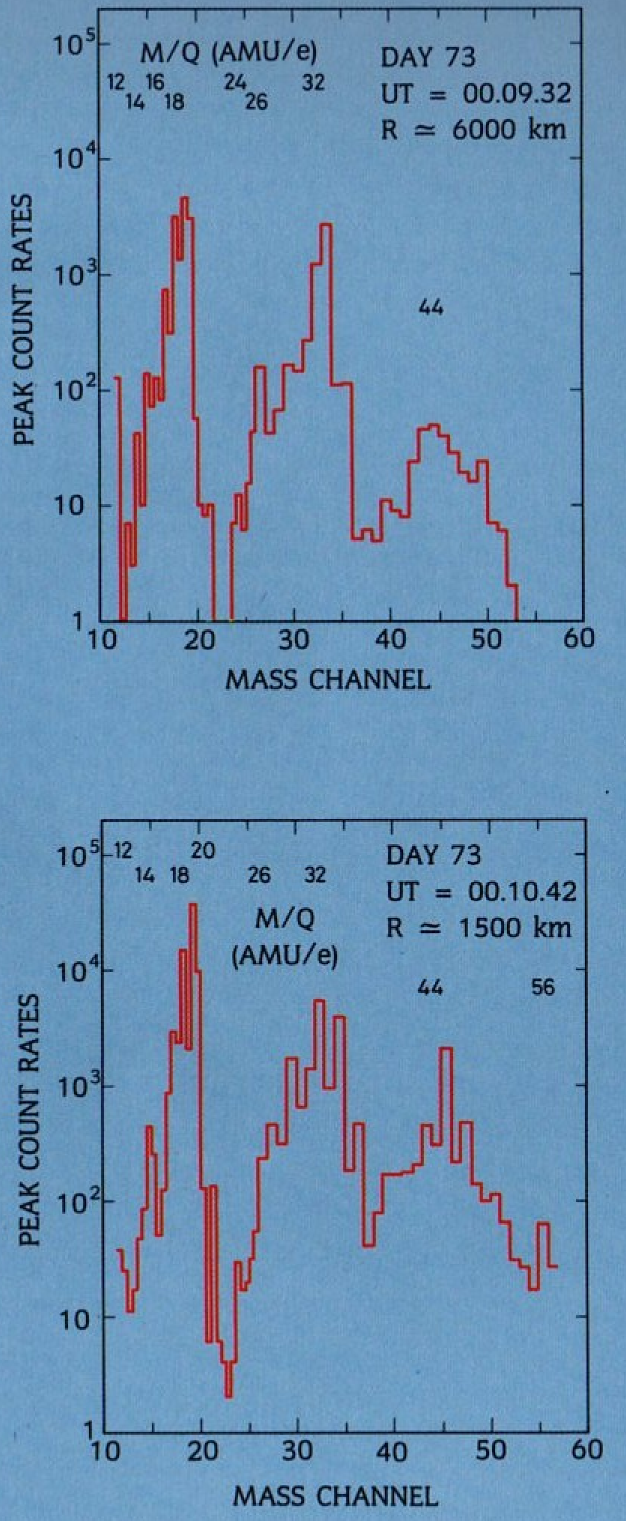
核より25,000km以内における磁場および彗星イオンの観測。最近接に先立つ16,400kmのところで磁場強度（下のパネル）は最大値57 nTに達した（磁場の堆積する領域）。この後、磁場は急速に減じ始め、接触不連続面の内側では本質的にはゼロとなった。この面は最近接に先立つ4,700kmの所で横切られた。探査機はこの磁場の「空洞」の内側に約2分間滞在していた。出ていく時に再びこの不連続面を横切ったがそれは最近接の後3,800kmの所であった。その後磁場は急速に増大し最近接後8,200kmのところで、入って来た時の極大値を凌ぐ極大値65nTを記録した。これらの磁場観測がなされたのと時を同じくして、着実に減少して行くイオン温度（中央のパネル）やイオン速度（上のパネル）が原子質量単位で18(H_2O^+)と19(H_3O^+)の所で観測された。接触不連続面を横切ったとき、温度は突然2,600Kから450K以下に低下した。この温度の低下は彗星から～1km/s程度の速さで外に流れ出て行く流体の突然の出現と一致している。図の最上部には、6,000km(接触不連続面の外側）と、1,500km（接触不連続面の内側）における2つの代表的なイオンの質量スペクトルが示されている。この2つの質量スペクトルを較べると、核からの距離によってイオン組成が相当に変化しているのが見てとれる。何千ものこのような質量スペクトルがジョットに搭載された2種類の気体（中性、イオン）質量分析計により得られた。既に多くのイオンや中性の分子種が同定可能であるが、彗星コマ中で生じている複雑な連鎖をもった化学過程を明らかにするにはなおはるかに多くの解析が必要である。

European Space Agency (ESA)

Magnetic field and cometary ion observations within 25000 km from the nucleus. 16400 km before closest approach (CA) the magnetic field magnitude (lower panel) reached a maximum of 57 nT (magnetic pile-up region). Afterwards the magnitude started to decrease rapidly, to essentially zero inside the contact surface, which was crossed at 4700 km before CA. The spacecraft was inside this magnetic 'cavity' for about 2 minutes. On the outward bound pass the contact surface was crossed at 3800 km after CA and the magnetic field magnitude rose rapidly to reach an even higher maximum of 65 nT at 8200 km after CA. At the same time as these magnetic field observations were made, a steadily decreasing ion temperature (middle panel) and velocity (upper panel) were observed at 18 (H_2O^+) and 19 (H_3O^+) atomic mass units. When crossing the contact surface the temperature suddenly dropped from 2600 to less than 450 K. This drop in temperature coincided with a sudden onset of a ~ 1 km/s flow of ions outwards from the comet. On the right-hand side of the figure two representative ion mass spectra are shown at 6000 km (outside the contact surface) and at 1500 km (inside the contact surface). A comparison of the two mass spectra indicates substantial changes in ion composition in relation to the distance from the nucleus. Many thousands of such mass spectra were obtained by the two gas (neutrals and ions) mass spectrometers aboard Giotto and although many ionic and neutral species can already be identified much more analysis is needed to unravel the complex chain of chemical processes occurring in the cometary coma.



v_r (km/s)
3
2
1
M19
M18
T(K)
10^4
10^3
10^2
M19
M18
C
MAGNITUDE (nT)
64
32
0
SPIN AVERAGES
−25 000
−10 000
CA
+10 000
+25 000 km



PEAK COUNT RATES
10^5
10^4
10^3
10^2
10
1
M/Q (AMU/e)
12 14 16 18 24 26 32
DAY 73
UT = 00.09.32
R ≃ 6000 km
44
10 20 30 40 50 60
MASS CHANNEL
PEAK COUNT RATES
10^5
10^4
10^3
10^2
10
1
12 14 18 20 26 32
M/Q (AMU/e)
DAY 73
UT = 00.10.42
R ≃ 1500 km
44
56
10 20 30 40 50 60
MASS CHANNEL

Intercosmos

Photos fausse couleur du noyau de la comète prises par la caméra de la sonde Vega 2 le 9 mars 1986. La photo du bas a été prise à 07.19.58 TU, soit deux secondes avant l'approche au minimum de distance, à 8030 km du noyau, avec un filtre proche infrarouge (700 – 900 nm). La photo du haut a été prise à 07.21.39 TU, à 11 037 km du noyau, avec un filtre transparent (400 – 650 nm). Sur la première photo, le Soleil est orienté vers le coin inférieur à gauche, à 113° de l'axe vertical de l'image. Sur la seconde, il est orienté vers le coin inférieur à droite, à 125° de la verticale. Les deux instants de prise de vues sont marqués sur la trajectoire de Vega. L'angle de phase (angle formé par les lignes joignant d'une part la sonde à la comète, et d'autre part le Soleil à la comète) est de 28,5° sur la photo inférieure et de 23° sur la photo supérieure. Le noyau a l'aspect d'une cacahuète de 16 × 8 × 8 km de dimensions. La région entourant le noyau est brillante en raison de la réflexion de la lumière solaire par les particules de poussière. D'abondants jets de poussière, qui proviennent de certaines zones riches en poussière de la chevelure, sont projétés à partir du noyau essentiellement vers le Soleil (c'est-à-dire, vu en projection, vers l'observateur).

Интеркосмос

Псевдоцветные снимки ядра кометы Галлея, сделанные камерой на борту космического аппарата ВЕГА-2 9 марта 1986 г. Нижний снимок получен в 07:19:58 UT, за две секунды до момента наибольшего сближения с расстояния 8030 км от ядра с использованием фильтра ближней инфракрасной области (700-900 нм).

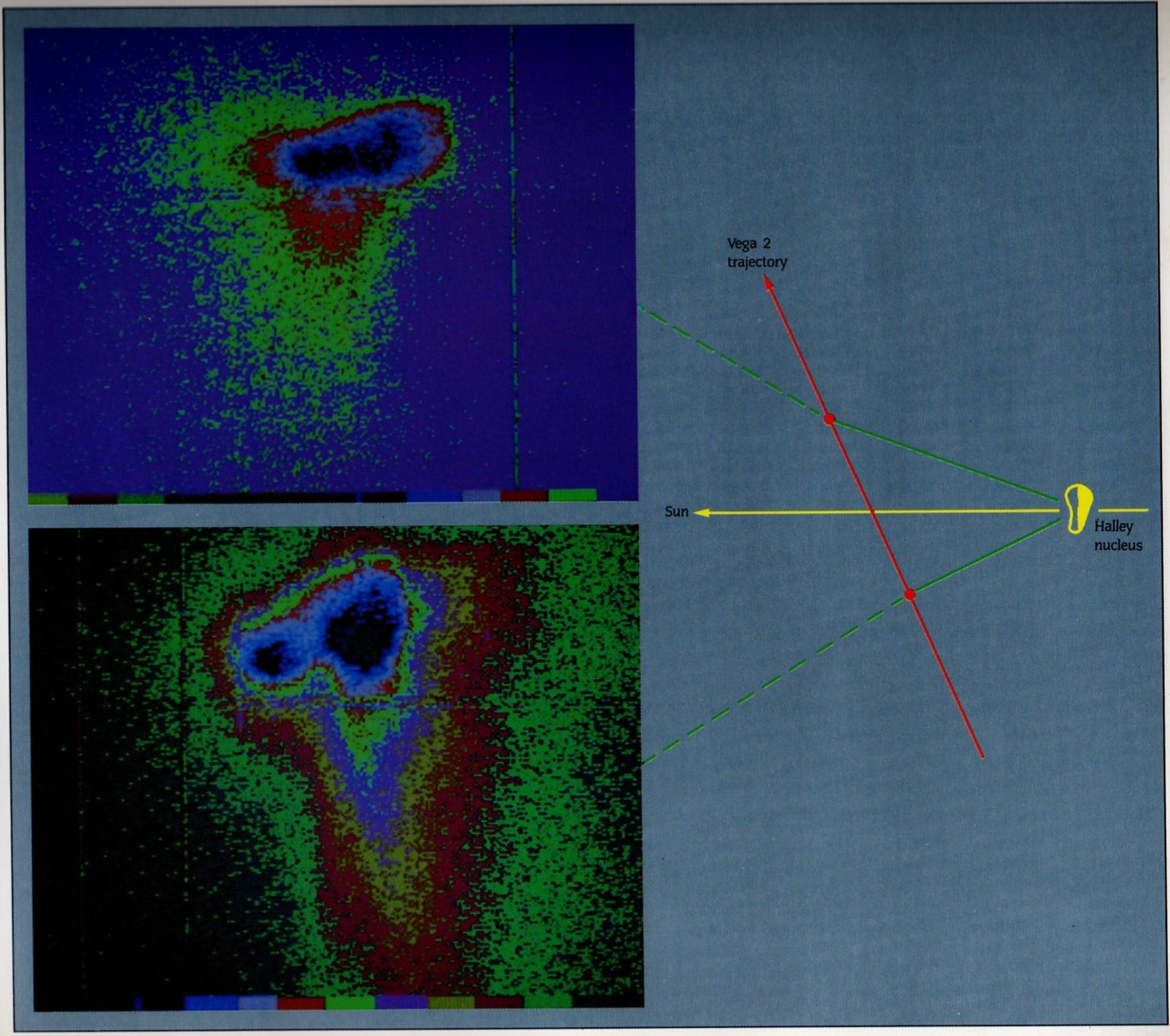
Верхний снимок был сделан в 07:21:39 UT с расстояния в 11037 км с использованием фильтра 400-650 нм. На нижнем снимке Солнце находится в нижнем левом углу, в направлении 113 градусов от вертикальной оси снимка. На верхнем снимке Солнце находится в нижнем правом углу в направлении 125 градусов от вертикали. Две точки, с которых были сделаны снимки, указаны на линии, изображающей траекторию космического аппарата ВЕГА. Фазовый угол (угол между линиями космический аппарат—комета и Солнце—комета) равен 28.5° на нижнем снимке и 23° на верхнем снимке. Разрешение 120 м на ячейку на нижнем снимке и 160 м на верхнем снимке. Ядро кометы представляется как асферичный объект, напоминающий формой земляной орех с предельными размерами 16×8×8 км. Область, окружающая ядро, кажется яркой благодаря солнеченомъ свету, отраженному пылевыми частицами. Выступающие пылевые джеты, области в кометной коме с высокой концентрацией пыли, направлены от ядра преимущественно к Солнцу, т.е. по направлению к наблюдателю, и они видны в проекции.

インターコスモス

ヴェガ2号搭載のカメラにより1986年3月9日撮影されたハレー彗星の核の擬似カラー写真。下の画像は最接近に先立つ2秒前、7時19分58秒UTに核から8,030kmの距離で撮られた。近赤外フィルター（700～900nm）を使っている。上の画像は7時21分39秒UTに、11,037kmのところでフィルターなしのモード（400～650nmに感ずる）で撮られた。下図においては太陽は左下方、像の垂直軸より113°の方向にあり、上図においては太陽は右下方、同軸より125°の方向にある。2つの画像の撮影された地点がヴェガの軌道図上に書き込まれている。位相角（探査機－彗星、太陽－彗星の2線分のなす角）は下図においては28.5°、上図においては23°である。図の分解能は下図では1ピクセル120mであり、上図では1ピクセル160mになっている。彗星核はピーナツ型をした非球状物体のようになっている。全体的な大きさは16×8×8kmである。核を取り巻く領域はダスト粒子の反射する太陽光のため明るくみえる。顕著なダスト・ジェット（あるいは彗星コマ中の高いダスト密度をもった領域といってもよいが）は核から本質的には太陽の方向にのびている。

Intercosmos

False colour images of the nucleus of Halley's Comet taken by the camera on board the Vega 2 spacecraft on 9 March 1986. The lower image was taken at 07:19:58 UT, two seconds before closest approach, at a distance of 8030 km from the nucleus, using a near-infrared filter (700 - 900 nm). The upper image was taken at 07:21:39 UT, at a distance of 11037 km, using a clear filter (400 - 650 nm). In the lower image the direction of the Sun is towards the lower left hand corner, 113° from the vertical axis of the image. In the upper image the direction of the Sun is towards the lower right hand corner, 125° from the vertical. The two points at which the images were taken are indicated on the line drawing of the Vega trajectory. The phase angle (the angle between the spacecraft - comet and the Sun - comet lines) is 28.5° in the lower image and 23° in the upper image. The resolution is 120 m per pixel in the lower image, and 160 m in the upper image. The comet nucleus appears as an aspherical peanut-shaped object with overall dimensions of 16 x 8 x 8 km. The region surrounding the nucleus appears bright due to sunlight reflected by dust particles. Prominent dust jets, regions in the cometary coma with a high concentration of dust, are directed from the nucleus essentially towards the Sun, i.e. towards the observer they are seen in projection.

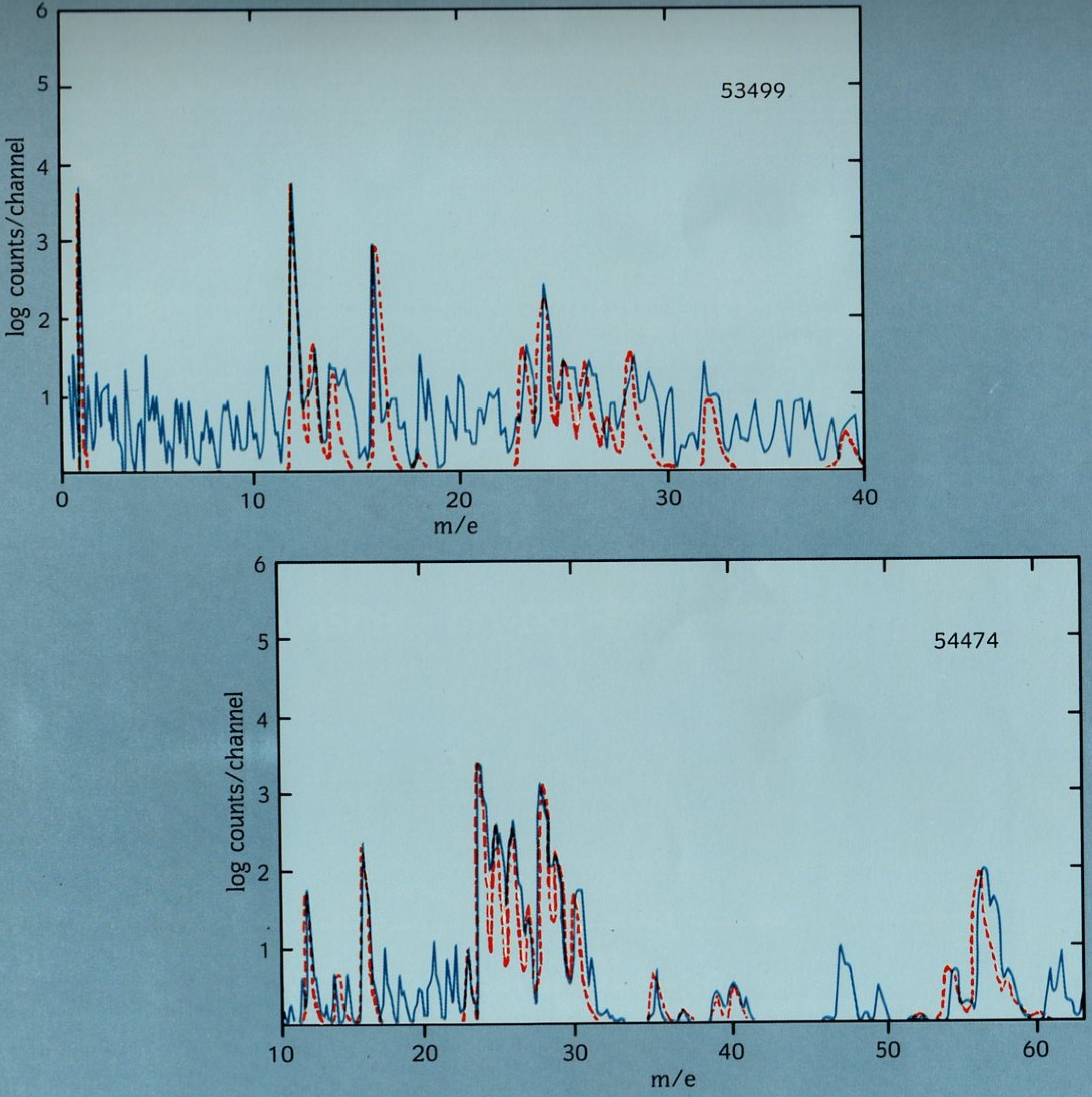

Vega 2
trajectory
Sun
Halley
nucleus

インターコスモス

ダスト質量分析計（PUMA）により観測されたダスト粒子質量スペクトルの2例。横軸はダスト粒子を作っている元素の質量を原子質量単位で表わしたものであり、縦軸はイオンカウント/チャネルを対数スケールで表わしたものである。右上隅の数は収得データの参照番号である。観測されたスペクトル（太い実線）はダスト粒子の組成を直接に反映してはいない。測定器中の標的に彗星のダスト粒子がぶつかると、それは蒸発し、かつ部分的に電離されるが、その電離効率は元素ごとに異っているからである。この電離効率について室内実験により確立されているものを使い観測スペクトルを補正したものがダスト粒子の合成スペクトル（細い点線）である。この2例は多くのスペクトルの中から、重い元素（Mg、Si、Fe）に対する軽い元素（H、C、N、O）の存在量の両極端に属するものとして選ばれた。イオンカウントという言葉でいえば、この比はNo.53499においては24であり、No.54474においては0.07である。しかし平均としてみれば、ハレーのダスト粒子の重元素の組成は因子2の許容範囲内でコンドライト的である。炭素はC1コンドライトに比べて8倍多く含まれている。その量は宇宙組成に大変近いものである。この相対的に大きな炭素存在量は非揮発性の炭素質成分の存在を指示するものである（炭素を含む氷の存在はヴェガのこの核からの距離では熱力学的に排除できる）。

Intercosmos

Mass spectra of two individual dust particles observed by the Dust Mass Spectrometer PUMA. The horizontal linear scale gives the mass of the elements of which the dust particle is composed in atomic mass units, while the vertical logarithmic scale gives the number of ion counts/channel. The number in the upper right hand corner is an internal reference number. The observed spectra (solid, thick lines) do not reflect directly the composition of the dust particle. Upon impact on the target in the instrument the cometary dust particle is vaporised and partly ionised, with a different ionisation yield for different elements. Taking ionisation yields as established by laboratory experiments the observed spectra are corrected to give synthetic spectra (dashed, thin lines) of the dust particle. The two spectra were selected from a large number of spectra; they illustrate the extremes in the ratio of the light elements (H,C,N,O) to the heavier elements (Mg, Si, Fe). In terms of ion counts this ratio is 24 for No. 53499 and 0.07 for No. 54474. On average, however, within a factor of two, the composition of the Halley dust particles is chondritic for the major elements. Carbon is enriched relative to C1 chondrites by a factor of eight, but is very similar to cosmic abundance. This relatively high C-abundance points to the presence of a refractory carbonaceous component since ices can be thermodynamically excluded at the distance of Vega from the nucleus.

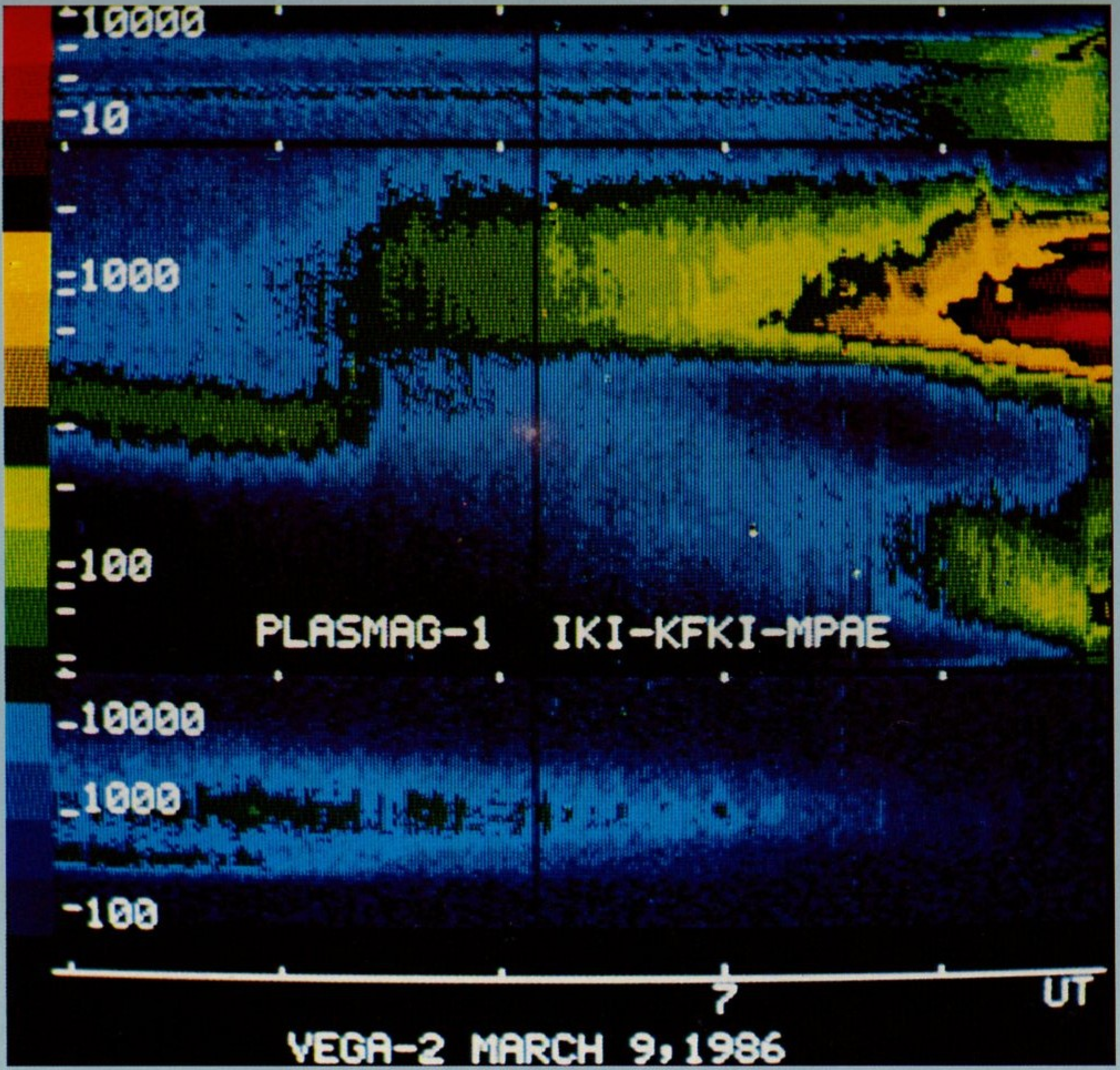

53499
log counts/channel
6
5
4
3
2
1
0
10
20
30
40
m/e
54474
log counts/channel
6
5
4
3
2
1
10
20
30
40
50
60
m/e

インターコスモス

核から230,000kmから14,000kmの距離の所で得られたヴェガ2号のプラズマ測定の概活。時間スケールでは1986年3月9日06:30時UTから07:17時UTに対応する（10分間隔でレが打たれている）。電子のスペクトルが上のパネルで、イオンのスペクトルがその下の2つのパネルである。中央のパネルは探査機の進行する方向（ラム方向）からやってくるイオンのスペクトルを、下のパネルは太陽風方向(横方向)のイオンのスペクトルを示す。縦軸はeVでの粒子のエネルギーを示し、色付けは強度の違いを表現し、赤が最大のフラックス、暗い青が最小のフラックスを表わす。ピーク強度を有するエネルギー値はプラズマの速度を与え、その周りの分布はプラズマの温度を与える。230,000kmにおいて太陽風プラズマは既に彗星イオンを相当に取り込んでおり約230km/sに減速されている（普通は400km/s)。彗星プラズマとの相互作用により、太陽熱プラズマは加熱され温度は約5×10^5Kになっている（普通は5×10^4K)。太陽風プラズマは太陽を中心とする動径方向より10～15°曲げられているが、それは彗星電離層を避けて流れねばならないからである。06:43時UTと06:45時UTの間（核から160,000km）に、ヴェガ2号は異なった化学組成の2つのプラズマ領域を隔てている鋭い境界面（cometopause）を横切り、彗星のプラズマ域に入った。相当量のプロトン束（200～300eVにピークをもつ）が、太陽風方向イオン検出器によっては彗星プラズマ域の外側においてのみ検出され、ラム方向検出器によっては50,000km（07：10時UT）より内側においてのみ検出された。重イオン（約1000eVにピークがある）は太陽風方向検出器によって約50,000kmに達するまで検出された。この重イオンはゆっくりと同検出器から消えて行くとともに、それらは徐々にラム方向検出器に姿を表わしている。高い強度の電子束が50,000kmより内側で観測されたが、そこでは1000 eVを越えるエネルギーのものさえ見つかっている。

Intercosmos

Colour coded summary representation of the Vega 2 plasma measurements between 230000 km and 14000 km from the nucleus, corresponding to 06.30 and 07.17 UT, 9 March 1986 on the time scale (tick-marks are 10 minutes apart). Electron spectra are shown in the upper panel, ion spectra in the lower two panels. The middle panel shows spectra as observed in the ram direction (forward), the lower panel spectra in the solar direction (sidewards). The ordinate gives particle energy in eV, colour coding represents intensity, with red corresponding to the highest fluxes, and dark blue to the lowest fluxes. The energy of the peak intensity gives the plasma velocity, the width of the distribution the plasma temperature. At 230000 km the solar wind plasma is already heavily mass-loaded with cometary ions, and has decelerated to about 230 km/s (normally 400 km/s). Due to the interaction of the cometary plasma, the solar wind plasma is heated, having a temperature of about 5×10^5 K (normally 5×10^4 K). It is deflected by 10° - 15° from the normal radial direction from the Sun, as it has to flow around the cometary ionosphere. Between 06.43 and 06.45 UT (160000 km) Vega 2 crosses a sharp boundary (*cometopause*) separating two plasma regions of different chemical composition and enters the cometary plasma region. Significant fluxes of protons (peak at a few hundred eV) are detected by the solar direction sensor only outside the cometary plasma region, and by the ram sensor only within 50000 km (07.10 UT). Heavy ions (peak at about 1000 eV) are detected by the solar direction sensor until about 50000 km. While the heavy ions slowly disappear from the solar direction, they show up more and more strongly in the ram direction. High intensity fluxes of electrons are observed inside 50000 km, even at energies >1000 eV.


10000
10
1000
100
PLASMAG-1 IKI-KFKI-MPAE
10000
1000
100
7
UT
VEGA-2 MARCH 9,1986

ISAS — Japon

Graphique montrant les pointes d'activité de la chevelure d'hydrogène de la comète de Halley observées par le satellite Suisei à la longueur d'ondre de la raie Lyman-α (les dates sont en ordonnées, les temps en abscisses). On y observe que la brillance de la raie Lyman-α atteint une pointe toutes les 52,9 heures, signe probable de la présence d'un noyau d'activité non uniforme accomplissant un tour sur lui-même au cours de la même durée. Les triangles rouges correspondent aux pointes d'activité. La ligne bleue reliant les triangles rouges s'incurve nettement vers le centre de la figure (effet dû à l'anomalie vraie), mais devient presque verticale aux deux extrêmes. Aucune observation n'a été faite entre la mi-décembre et le début de février. V1, V2, Su, Sa et G correspondent respectivement aux moments du survol par Vega 1, Vega 2, Suisei, Sakigake et Giotto. Les traits minces en vert représentent les périodes d'observation dans l'ultraviolet, tandis que (c) et (d) indiquent les époques des deux observations représentées à droite, sur lesquelles figurent des exemples de variation de brillance.

Институт космонавтики и астронавтики (ISAS) — Япония

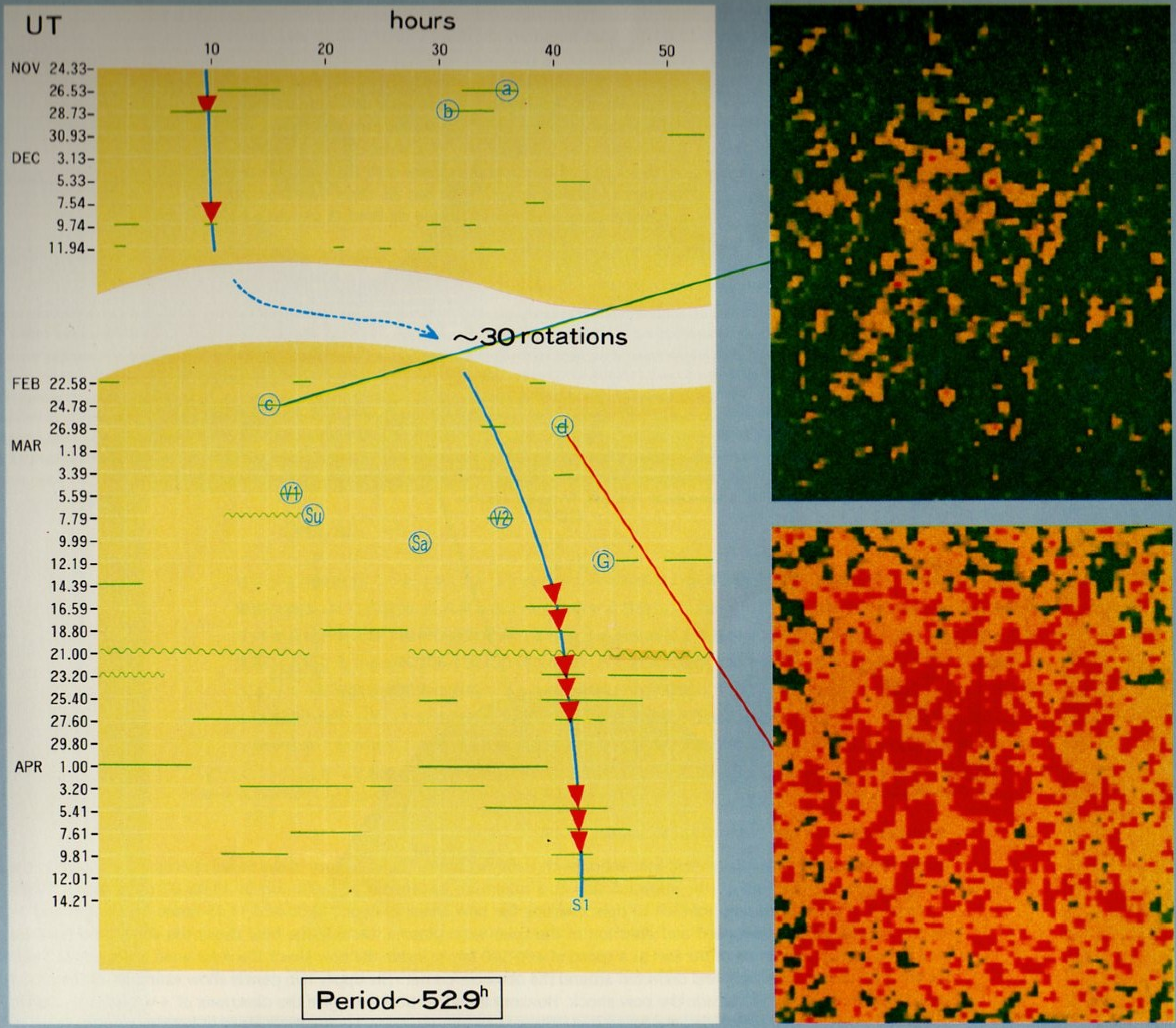
Пики активности водородной комы кометы Галлея наблюдались с помощью изображений, в линии Лаймай-α, полученных с помощью фотометра, установленного на борту космического аппарата Suisei. На этом графике время представлено, как строчки в книге. Определено, что Лиман-α яркость достигает максимума каждые 52,9 часа, что интерпретируется как признак неоднородно активного ядра с периодом вращения 52,9 часа. Красные треугольники показывают время пиков активности. Синяя кривая, соединяющая красные треугольники, заметно меняет направление в центре рисунка в результате влияния истинной аномалии, но она почти вертикальна в самой верхней и самой нижней части рисунка. С середнины декабря до начала февраля наблюдений не проводилось V1, V2, Su, Sa, G обозначают моменты пролетов космических аппаратов ВЕГА-1, ВЕГА-2, Suisei, Sakigake и Джотто, соответсвенно, Зелеными кривыми показано время УФ наблюдений, (c) и (d) обозначено время двух наблюдений вариации яркости, показанных на примерах справа.

宇宙科学研究所（ISAS）—— 日本

探査機“すいせい”に搭載されたライマン・アルファ撮像装置により観測されたハレー彗星水素コマの活動度のピーク。ライマン・アルファ輝度が52.9時間毎にピークに達するのが見てとれるが、これは活動度が一様でない彗星核が、52.9時間の周期で自転していることを示すものと解釈される。赤い三角形は活動度のピークの時刻を表わす。赤い三角形をつないでいる青い曲線は、彗星の真近点離角の動きのために図の中央部においてかなり変化するが、その上方あるいは下方においてはほとんど直線である。1月の中旬から2月初めにかけてこの観測の休止期があった。V1、V2、Su、S_a、Gはそれぞれ、ヴェガ1号、ヴェガ2号、すいせい、さきがけ、ジョットとのハレー遭遇の時刻を表わしている。薄い緑の横線は紫外観測のなされた時間帯を示し、(c)、(d)は明暗変動の例を示すものとして右方に2枚の写真で示されている観測がなされた時刻を表わす。

Institute of Space and Astronautical Science (ISAS)

Activity peaks of the hydrogen coma of Halley's Comet observed with the Lyman-α Imager on board the Suisei spacecraft. In this plot, time runs like the lines in a book. It is found that the Lyman-α brightness reaches a peak every 52.9 hours which is interpreted as being the signature of an inhomogeneously active nucleus with a rotation period of 52.9 hours. The red triangles indicate the time of activity peaks. The blue curve connecting the red triangles turns appreciably in the centre of the figure due to the effect of the true anomaly but is almost vertical at the uppermost and lowermost portions. No observations were made from mid-December to early February. V1, V2, Su, Sa, G denote the times of the Vega 1, Vega 2, Suisei, Sakigake and Giotto encounters, respectively. Thin green lines represent times when UV observations were made, (c) and (d) mark the times of the two observations shown at the right displaying examples of the brightness variation.


UT
hours
10
20
30
40
50
NOV 24.33
26.53
28.73
30.93
DEC 3.13
5.33
7.54
9.74
11.94
~30 rotations
FEB 22.58
24.78
26.98
MAR 1.18
3.39
5.59
7.79
9.99
12.19
14.39
16.59
18.80
21.00
23.20
25.40
27.60
29.80
APR 1.00
3.20
5.41
7.61
9.81
12.01
14.21
a
b
c
d
V1
Su
V2
Sa
G
S1
Period~52.9h

ISAS — Japon

Observations par Suisei des interactions du vent solaire avec la comète de Halley. La trajectoire de la sonde, qui figure dans le cadre inférieur, dépasse le noyau du côté Soleil le 8 mars 1986 à 13.06 TU à un minimum de distance de 151 000 km. Suisei traverse la chevelure de la comète de gauche à droite, pénétrant à l'intérieur du front de choc vers 11.00 heures pour en ressortir vers 14.45 heures. La longueur et la direction des flèches indiquent la vitesse et la direction du plasma solaire. A l'extérieur du front de choc de la comète, le vent solaire circule normalement à la vitesse de 400 à 500 km/s; à l'intérieur de l'onde de choc, il se trouve ralenti et dévié par l'obstacle constitué par la comète (sa vitesse descendant à 56 km/s au plus près de celle-ci). Les deux cadres du haut montrent des exemples de la densité ionique dans l'espace de phase de part et d'autre du front de choc. Les axes horizontaux et verticaux correspondent aux directions de $+V_x$ et $+V_y$. Les différences d'intensité sont traduites par des différences de couleurs, la plus forte intensité étant en rouge. Des structures annulaires apparaissent sur les deux exemples: on pense qu'elles correspondent à la section écliptique de la coquille de capture pour les ions du groupe de l'eau (à gauche), les ions H (petit rond à droite) et les ions O (grand rond à droite).

Институт космонавтики и астронавтики (ISAS) — Япония

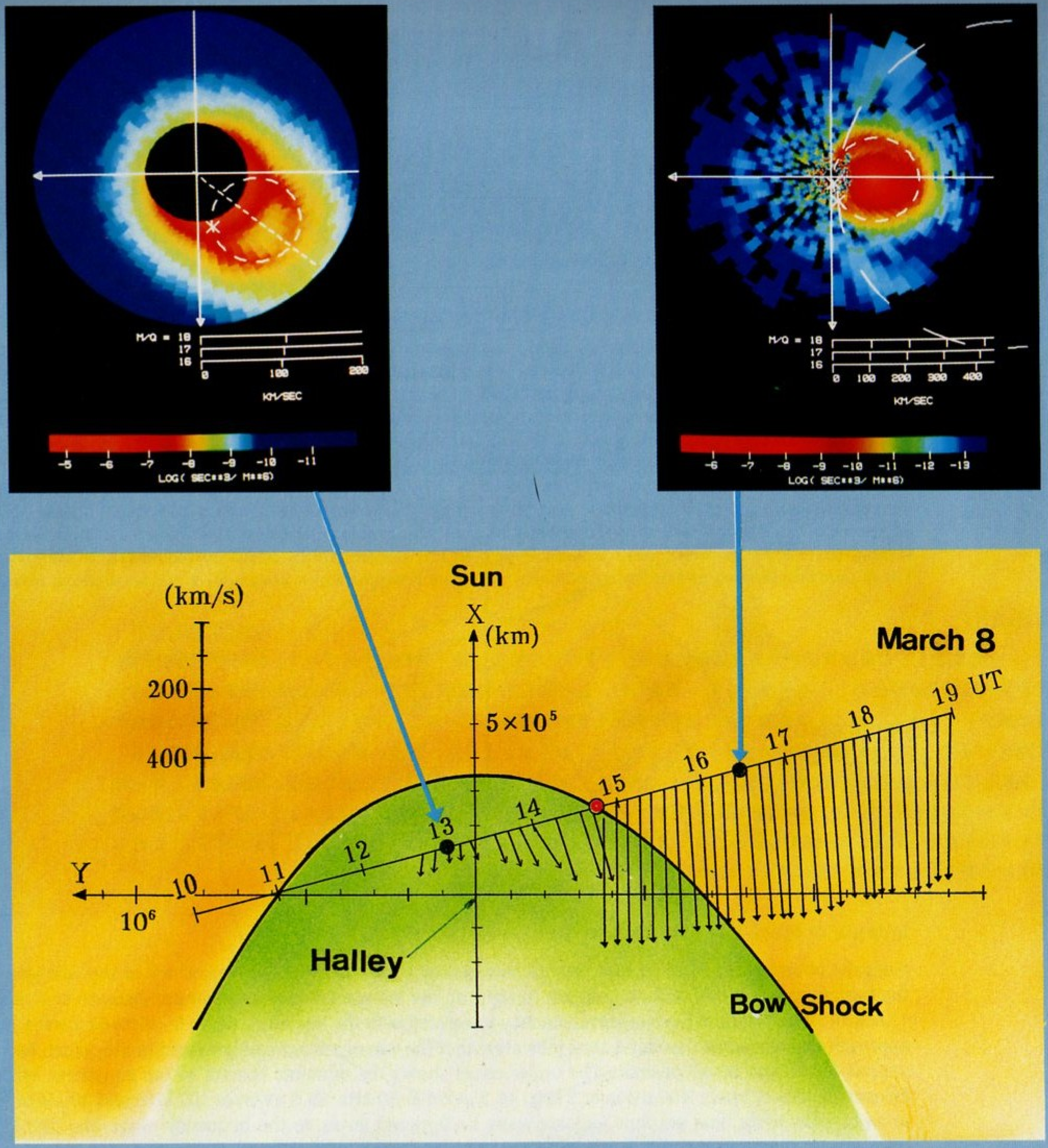
Наблюдения на борту космического аппарата Suisei взаимодействия солнечного ветра с кометой Галлея. В нижней части рисунка показана траектория КА, пролетевшего мимо ядра с солнечной стороны на минимальном расстоянии 151.000 км в 13.06 UT 8 марта 1986 г. Suisei прошел через кометную кому слева направо и пересек головную ударную волну в примерно 11.00 и 14.45. Длина и направление стрепок указывают скорость и направление плазмы солнечного ветра. Вне головной ударной волны солнечный ветер невозмущен и течет от Солнца со скоростью 400-500 км/с; внутри головной ударной волны солнечный ветер заторможен /минимум 56 км/с на ближайшем расстоянии/ и отклонен вокруг препятствия „кометы". На верхних двух рисунках показаны примеры распределения ионов в фазовом пространстве во внутренней и в нешних областях от головной ударной волны. По горизонтальной и вертикальной осям покозаны направления скоростей $+V_x$ и $+V_y$. Разные интенсивности окрашены в разные цвета, красный цвет — наибольшая интенсивность. На обоих примерах видны кольцевые структуры. Их интерпретируют как эклиптическое сечение области захвата ионов водной группы /слева/ и ионов водорода /справа, маленькие кружки/ и кислорода /справа, большие кружки/.

宇宙科学研究所（ISAS）—— 日本

“すいせい”によるハレー彗星と太陽風相互作用の観測。同探査機の軌道は下のパネルに示されている。“すいせい”は1986年３月８日13.06UTに太陽側、ハレー彗星から151000kmの所を通過した。“すいせい”は彗星コマ中を左から右に進み11.00時及び14.45時に衝撃波面を横切った。矢印の長さと方向はそのときの太陽風プラズマの速さと方向を表わしている。衝撃波面の外側では太陽風は乱されておらず、太陽方向から400～500km/sの速さで流れている。内側では太陽風は減速され（最接近時には最小速度56km/sにまで減速）障害物としての彗星によりまげられている。上方の２つのパネルはそれぞれ衝撃波面の内外でのイオンの速度分布関数の例を示している。横軸及び縦軸はそれぞれ$+V_x$，$+V_y$の方向になっている。色の違いは強度の違いを表わし、赤が最大の強度を示す。リング状の構造がこれらの図にあらわれている。この構造は磁力線に捕捉されたイオンの速度空間における黄道面断面図と解することができ、水分子族イオンに対するものが左側に、水素イオンに対するものが右側の小円、酸素イオンに対するものが右側の大円で示されている。

Institute of Space and Astronautical Science (ISAS)

Suisei observations of the solar wind interaction with Halley's Comet. The trajectory of the Suisei spacecraft is shown in the lower panel passing the nucleus on the sunward side at a minimum distance of 151 000 km at 13.06 UT on 8 March 1986. Suisei traverses the cometary coma from left to right crossing the bow shock at about 11.00 and 14.45 hours. The length and direction of the arrows indicate the speed and direction of the solar wind plasma. Outside the bow shock the solar wind is undisturbed and flows from the direction of the Sun at a speed of 400-500 km/s; inside the bow shock the solar wind is decelerated (minimum 54 km/s at closest approach) and deflected around the obstacle 'comet'. The upper two panels show examples of the phase space density of ions inside and outside the bow shock. Horizontal and vertical axes give the directions of $+V_x$ and $+V_y$. Different colours represent different intensities, red being the highest intensity. Ringlike structures are seen in both examples. They are interpreted as the ecliptic cross section of the pick-up shell for water-group ions (left) and H^+ (right, small circle) and O^+ (right, large circle) ions.


M/Q = 18
17
16
0
100
200
KM/SEC
-5
-6
-7
-8
-9
-10
-11
LOG(SEC**3/ M**6)
M/Q = 18
17
16
0
100
200
300
400
KM/SEC
-6
-7
-8
-9
-10
-11
-12
-13
LOG(SEC**3/ M**6)
Sun
(km/s)
200
400
X (km)
5×10⁵
March 8
19 UT
18
17
16
15
14
13
12
11
10
Y
10⁶
Halley
Bow Shock

ISAS — Japon

Observations par Sakigake des ondes radioélectriques et plasmatiques dans le voisinage de la comète de Halley. La trajectoire de la sonde (à droite) dépasse le noyau du côté Soleil pour s'approcher à 7 millions km le 11 mars 1986 à 04.18 TU. L'intensité totale des ondes plasmatiques dans la fréquence 5 – 190 kHz (au centre) augmente à l'approche de la comète pour ensuite décroître, prouvant ainsi que ces ondes sont étroitement liées à la présence de la comète. Les flèches rouges indiquent la position de la sonde aux moments des observations. Le panneau du haut représente les spectres dynamiques des émissions: les parties en jaune correspondent aux niveaux d'intensité suivants: 400 μV/m à 5 kHz, 46,2 μV/m à 50 kHz, 35,6 μV/m à 100 kHz, et 30 μV/m à 200 kHz; les parties en rouge correspondent au double des niveaux précédents et les bleues aux faibles bruits de fond. On observe que, dans la gamme 20 – 190 kHz, la fréquence s'accroît ou diminue graduellement en fonction du temps, ce qui correspond à la région où se forment les ondes de choc (c'est-à-dire vers 350 000 à 600 000 km). Dans la gamme de fréquence 5 – 80 kHz, on distingue des spectres de très forte intensité et à large bande (par exemple à 06.00 TU). On attribue ce phénomène aux ondes plasmatiques qui prennent naissance dans la zone de capture des ions.

Институт космических и астронавтических исследований (ISAS—Япония)

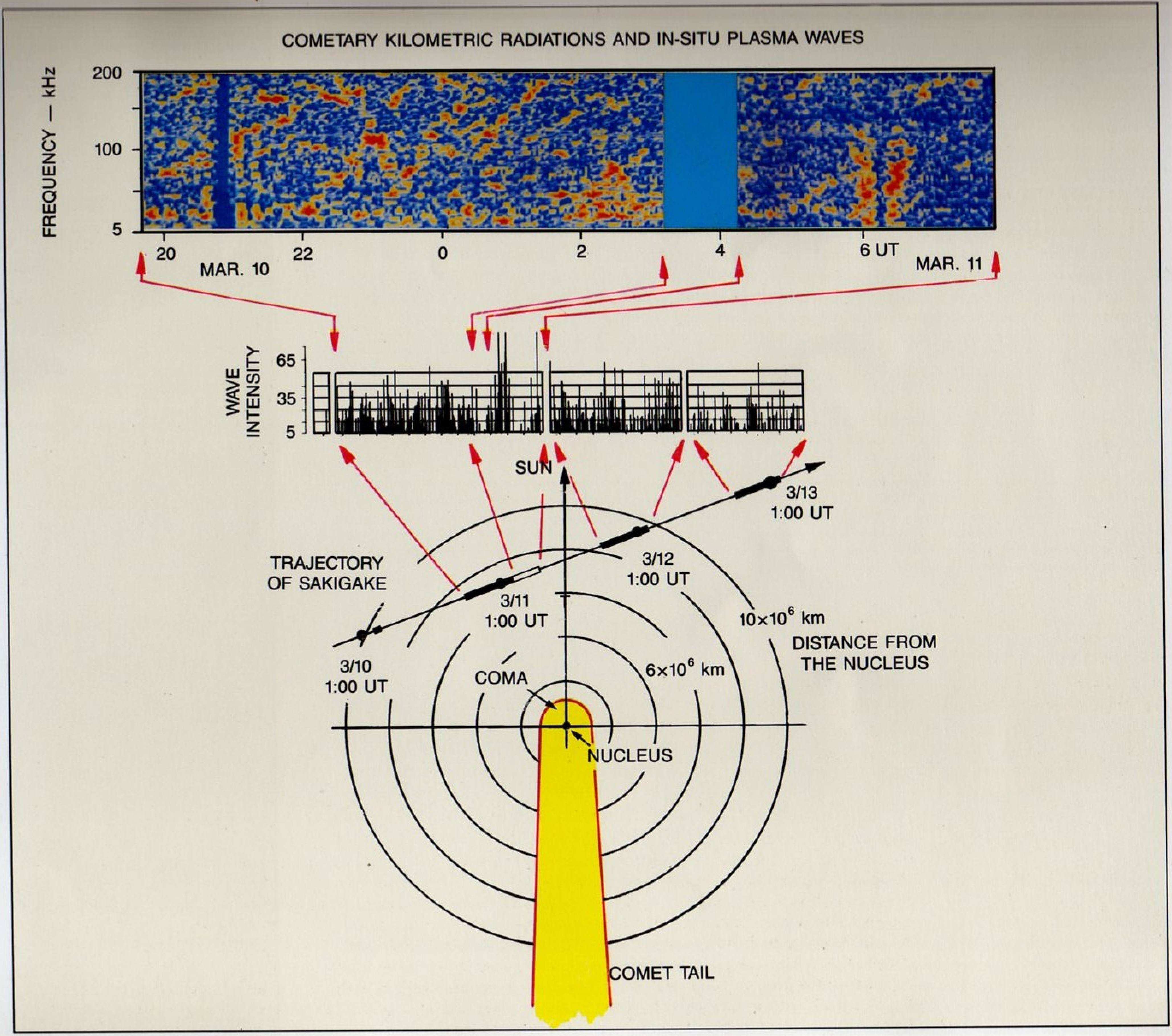
Наблюдения космическим аппаратом радио- и плазменных волн вбизи кометы Галлея. Траектория космического аппарата Сакигаке показана в нижней части рисунка. Он проходит около пдра кометы слева направо с подсолнечной на стороны минимальном расстоянии 7 млн. км в 04.18 UT 11 марта 1986 г. Общая интегральная интенсивность плазменных волн в диапазоне 5-190 кгц (в центре) возрастает при приближении к комете и убывает после прохождения ближайшего расстояния указывая таким образом на связь воли с кометой. Красные стрелки указывают положение аппарата в моменты наблюдений. В верхней части рисунка показан динамический спектр излугения. Жёлтый цвет соответствует следующим интенсивностям: 400 μν/м на 5 кгц, 46,2μν/м на 50кгц, 35,6 μν/м на 100 кгц, и 30 μν/м на 200 кгц; красный цвет — интенсивносям в два раза большим указанных, а голубой обозначает слабые фоновые уровни. В диапазоне 20-190 кгц наблюдались плавные увеличения или уменьшения частоты со временем, связанные с областью формирования ударной волны (от $3,5.10^5$ до 6.10^5 км). В диапозоне 5-80 кгц наблюдались очень интенсивные и широкие спектры (06.00 UT). Такие церты присущи плазменным волнам, которые генерируются локально в области сбора ионов.

宇宙科学研究所（ISAS）

〝さきがけ〞によるハレー彗星近くでの電波及びプラズマ活動の観測。さきがけの軌道は最下部に示されており、1986年3月11日04:18UTに、ハレー彗星から太陽側700万kmのところを左から右へ通過した。5—190KHzの帯域（図の中心部）の積分強度は最接近点に向って増加し、その後は減少している。このことは観測された活動が彗星と密接に関連していることを示している。赤い矢印は観測データを探査機の位置に関連づけている。上の図は輻射のダイナミックスペクトルを示している。黄色い部分は以下の強度に対応する：5KHzでは400μV/m、50KHzでは46.2μV/m、100KHzで35.6μV/m、200KHzで30μV/m。赤い部分はその倍の強度に対応する。青い部分は弱いバックグラウンドレベルを示している。20—190KHzの領域での振動数の時間変化が観測され、核から3.5×10^5—6×10^5km辺で発生した衝撃波に伴うものと考えられる。5—80KHz領域では、非常に強く、拡がったスペクトルが観測された（06:00UT）。これらはイオン捕捉領域で局所的に発生したプラズマ波に帰せられる。

Institute of Space and Astronautical Sciences (ISAS)

Sakigake observations of radio and plasma waves near Halley's Comet. The trajectory of the Sakigake spacecraft is shown at the bottom, passing the nucleus from left to right on the sunward side at a minimum distance of 7 million km at 04.18 UT on 11 March 1986. The total plasma wave intensity integrated over the frequency range 5 - 190 kHz (centre) increases towards closest approach and decreases thereafter, thus indicating that the waves are intimately related to the comet. Red arrows relate the observations to the spacecraft position. The upper panel shows the dynamic spectra of the emissions. Yellow portions refer to the following intensity levels: 400 μV/m at 5 kHz, 46.2 μV/m at 50 kHz, 35.6 μV/m at 100 kHz, and 30 μV/m at 200 kHz.; red portions to twice that, while blue portions indicate weak background levels. In the frequency range 20 - 190 kHz gradual increases or decreases of the frequency with time are observed which are associated with the region where shock waves are formed (3.5×10^5 to 6×10^5 km). In the frequency range 5 - 80 kHz very intense and broad band spectra are observed (e.g. at 06.00 UT). These features are attributed to plasma waves that are generated locally in the ion pick-up region.



COMETARY KILOMETRIC RADIATIONS AND IN-SITU PLASMA WAVES

NASA — Etats-Unis

Après avoir achevé sa mission d'exploration de l'espace interplanétaire qui l'a emmené à 1,5 million km de la Terre, le satellite d'étude des relations Soleil-Terre (ISEE-3) a été ramené en direction de la Terre. Ayant accompli un total de 37 manoeuvres de propulsion et cinq manoeuvres de gravidéviation autour de la Lune, le véhicule spatial, rebaptisé alors 'International Cometary Explorer' (ICE), s'est dirigé vers la comète de Giacobini-Zinner qu'il a survolée le 11 septembre 1985. Après avoir traversé la queue de cette dernière à une distance de 7800 km du noyau, ICE a poursuivi son chemin en direction de la comète de Halley dont il s'est approché à 30 millions km à la fin du mois de mars 1986.

НАСА-США

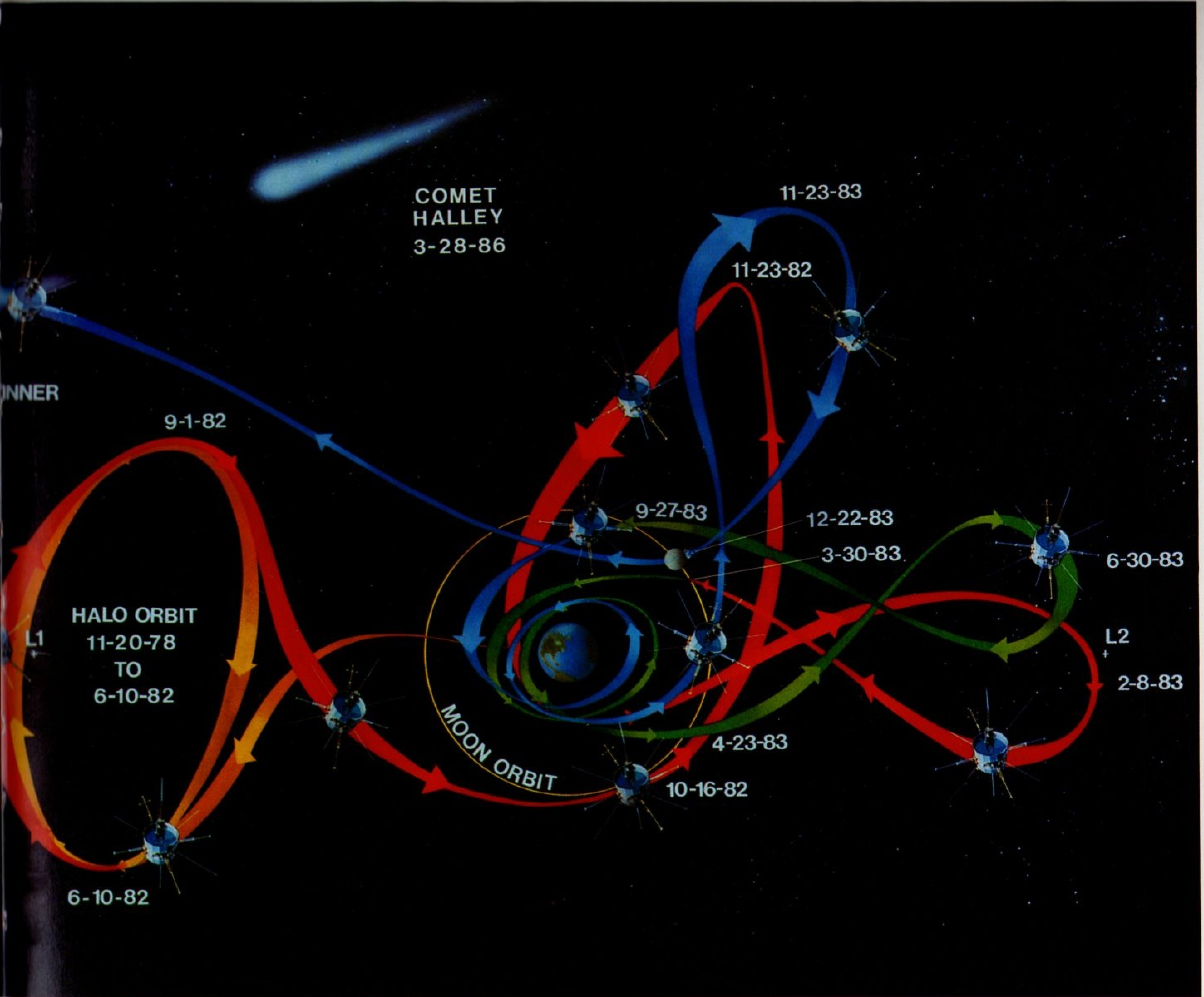
После выполнения программы своего полета как монитора в межплантеном пространстве 1,5 миллиона км от Земли космический корабль ISEE-3 /международный Солнце-Земля зонд/ был повернут в сторону Земли. После общей сложности 37 манеров с помощью двигательной устрановки и 5 манеров с использованием поля силы тяжести Луны космический корабль, затем перенаименованный как Международный кометный зонд ICE, был направлен к комете Джекобини Циннера, которую он пролетел 11 сентября 1985. ICE прошед сквозь хвост кометы на расстоянии 7800 км от ядра, прежде чем продолжить свой полет к комете Галлея. Он пересек комету Галлея в конце марта 1986 на расстоянии 30 миллионов км.

航空宇宙局（NASA）—— アメリカ

国際太陽地球観測探査機（ISEE-3）は地球から150万km離れた太陽風上流域にあたるところで惑星間空間をモニターする使命を果してきた。この衛星は地球に向う方向に軌道修正され、その後、37回もの燃料噴射制御と5回の月の重力を利用した軌道制御により国際彗星観測探査機（ICE）と改名され、ジャコビニ・ジンナー彗星に向かう軌道をとった。ICEは1985年9月11日に最接近を果し、核から7800kmの距離で尾の中を通過した。こののち、ハレーへの運航を続け、1986年3月の終りにハレーの上流3000万kmのところを通過した。

National Aeronautics and Space Administration (NASA)

After completing its mission as a monitor in interplanetary space 1.5 million km upstream from the Earth the International Sun Earth Explorer (ISEE-3) was redirected towards the Earth. After a total of 37 propulsive manoeuvres and 5 lunar gravity assist manoeuvres, the spacecraft, then renamed International Cometary Explorer (ICE), was on course towards Comet Giacobini-Zinner which it encountered on 11 September 1985. ICE passed through the comet's tail at a distance of 7800 km from the nucleus before continuing towards Halley's Comet. It passed Halley at the end of March 1986 at a distance of 28 million km upstream.


COMET HALLEY
3-28-86
11-23-83
11-23-82
INNER
9-1-82
9-27-83
12-22-83
3-30-83
6-30-83
HALO ORBIT
11-20-78
TO
6-10-82
L1
L2
2-8-83
4-23-83
MOON ORBIT
10-16-82
6-10-82

NASA — Etats-Unis

Photo en fausse couleur de la comète de Halley prise en lumière 'visible' par le détecteur de guidage fin du satellite international d'exploration dans l'ultraviolet (IUE) le 9 mars 1986. L'image couvre un champ de 12×12 minutes d'arc où chaque point élémentaire mesure environ 8 secondes d'arc au carré. Les zones sombres qui entourent la partie centrale de la comète correspondent à une portion faiblement réfléchissante sur la plaque et les ouvertures d'entrée du spectrographe. Le nord est en bas à gauche, l'est en bas à droite. (Photo NASA, avec l'aimable autorisation de P.D. Feldman, Johns Hopkins University).

НАСА-США

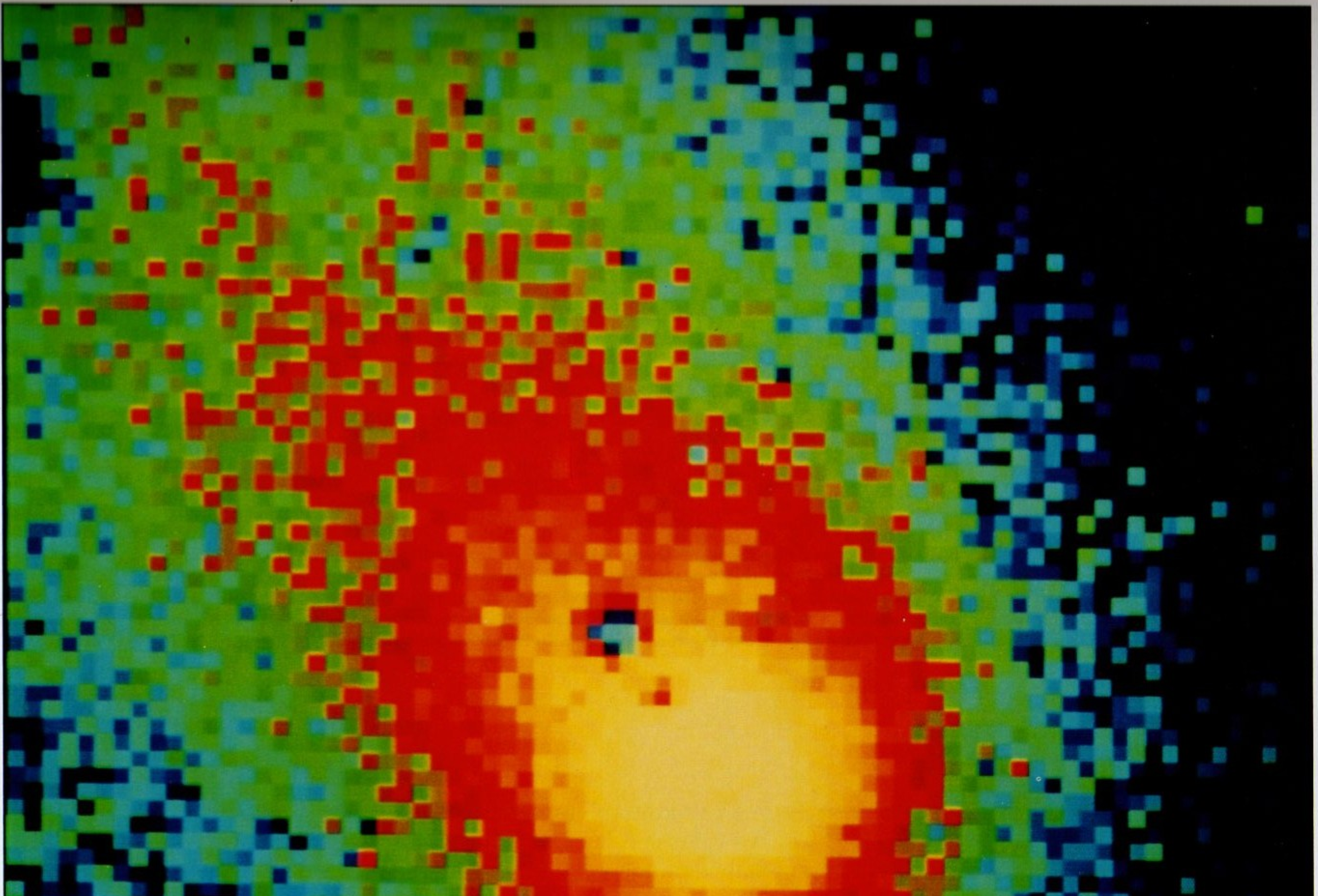
Фотография в условном цвете кометы Галлея в видимом диапозоне, полученная 9 марта 1986 г. высокоточным датчичком на спутниковой обсерватории IUE /международный ультрафиолетовый зонд/. Поле — 12 ч 12 угловых минут и каждый пиксел примерно квадрат размером 8 угловых секунд. Темные области вблизи центра кометы — пятно низкой отражательной способности в плоскости апертуры и входных аперетурах спектографа. Север вниз и налево, восток вниз и направо (фото НАСА).

航空宇宙局（NASA）—— アメリカ

国際紫外探査衛星（IUE）搭載の高性能検出器による可視光で1986年3月9日撮影されたハレー彗星の擬似カラー写真。視野は12分×12分角で個々のピクセルは約8平方秒角の大きさをもっている。彗星の中心近くにある暗い領域は開口板上の低反射率部分のためである。北は下方左側、東は下方右側に相当している。(写真提供はジョン・ホプキンス大学P.D.フェルドマン博士の好意による。)

National Aeronautics and Space Administration (NASA)

False colour photograph of Halley's Comet recorded in visible light by the Fine Error Sensor of the International Ultraviolet Explorer (IUE) satellite observatory on 9 March 1986. The field is 12×12 arc-minutes and each pixel is approximately 8 arc-seconds square. The dark regions near the centre of the comet are a low-reflectivity patch on the aperture plate and the spectrograph entrance apertures. North is down and to the left, and east is down and to the right. (NASA photo, courtesy of P.D. Feldman, Johns Hopkins University.)



NASA — Etats-Unis

Cette restitution en fausse couleur d'une image de la comète de Halley dans l'ultraviolet lointain montre les gradations à l'intérieur du nuage d'hydrogène de 20 millions km de large qui entoure la comète. Les caméras qui ont pris cette image ont été réalisées sous l'égide du Laboratoire de Recherche navale à Washington DC et de l'Université du Texas à Austin. Elles faisaient partie de la charge utile d'une fusée-sonde Black-Brant Terrier de la NASA, tirée à quelque 312 km d'altitude à partir de la Base de lancement de missiles de l'Armée à White Sands (Nouveau Mexique). L'image a été prise le 13 mars 1986, juste 13 heures avant le passage de la sonde européenne Giotto au plus près de la comète. (Photo NLR).

НАСА-США

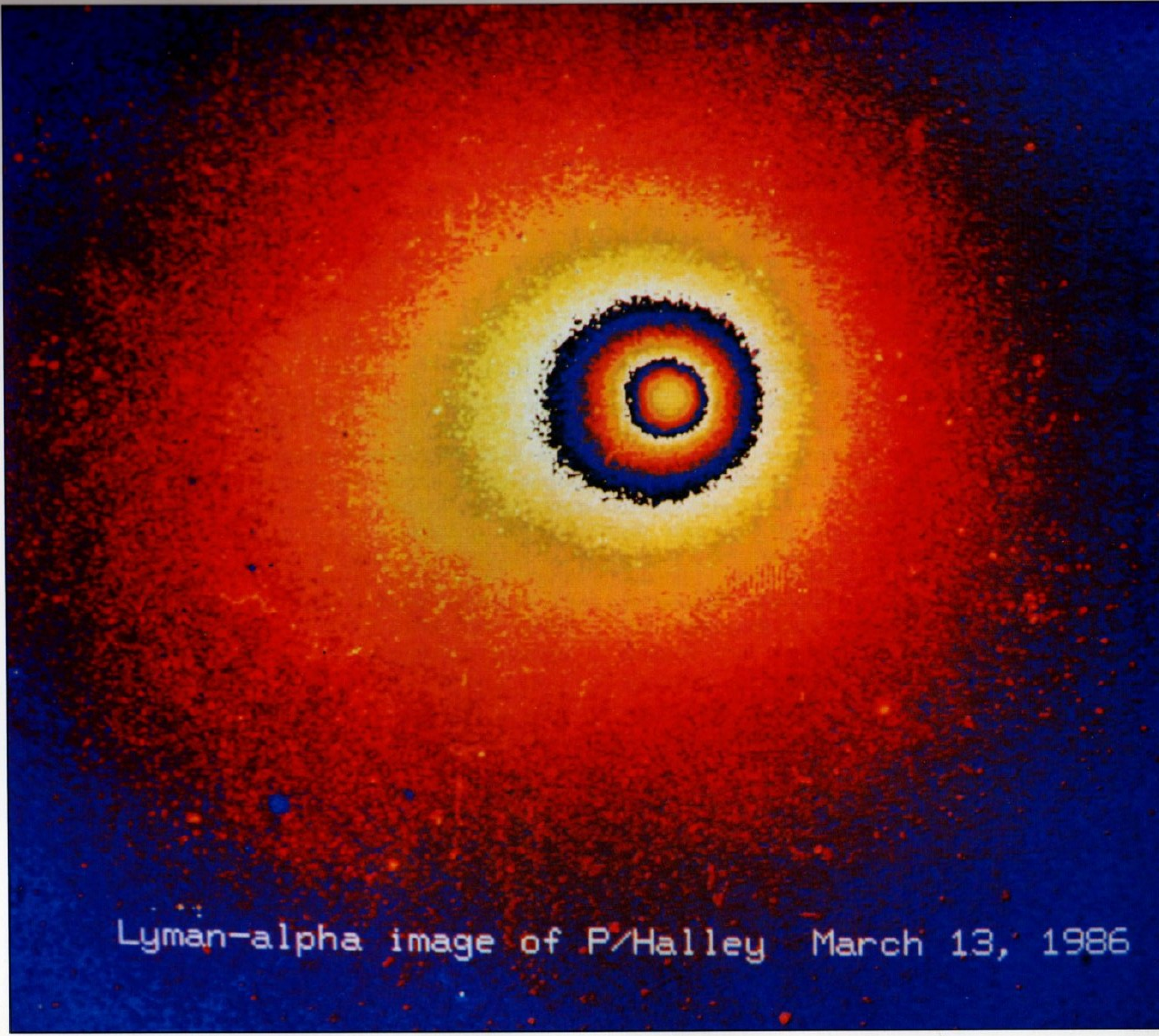
Изображение кометя Галлея в дальнем УФ диапазоне, полученное зондирующей ракетой, показывает распределение частиц в условных цветах в водородном облаке 20 миллионов км шириной, которое окружает комету. УФ камеры, которыми было получено изображение, были созданы научно-исследовательской лабораторией ВМС, Вашингтон, округ Колумбия, и Техасским университетом в Остине. Зондирующая ракета НАСА Black Brant/Terrier запущена с военного ракетного полигона Белые Пески, Нью-Мексико на высоту 194 мили с камерой на борту. Снимок был сделан 13 марта за 13 часов до ближайшего подхода КА Джотто /фото н/и лаборатории ВМС/.

航空宇宙局（NASA）—— アメリカ

ロケットによりとられたハレー彗星の遠紫外線での擬似カラー図。彗星をとりまく2000万kmもの幅の水素雲の存在を示している。この像をとった紫外線カメラはワシントンの海軍研究所とオースティンのテキサス大学が担当しているものである。米国航空宇宙局ブラックブラント／テリエ観測ロケットはホワイト・サンズの陸軍ミサイル発射場から打ち上げられ、カメラを194マイルの高度に運んだ。このハレー像は3月13日、ヨーロッパの探査機ジォットの最接近に先立つことちょうど13時間前に撮られた。

National Aeronautics and Space Administration (NASA)

Far-ultraviolet image of Halley's Comet taken by a sounding rocket shows false colour gradations in the 20 million km wide hydrogen cloud surrounding the comet. The ultraviolet cameras that made the image were sponsored by the Naval Research Laboratory, Washington D.C. and the University of Texas at Austin. A NASA Black Brant/Terrier sounding rocket fired from the Army's White Sands Missile Range N.M. carried the camera payload to an altitude of 194 miles. The image was made on 13 March, just 13 hours prior to closest approach by the European Giotto spacecraft. (NRL photo.)


Lyman-alpha image of P/Halley March 13, 1986

Dans cet exposé sur la création et les travaux du Comité consultatif inter-Agences, le Dr. R. Reinhard explique comment les efforts conjoints des organismes spatiaux dans la planification de la campagne, la conception des satellites et des expériences ainsi que l'exploitation des données ont contribué à renforcer la portée scientifique de la mission. Il décrit les travaux des trois groupes spécialisés du Comité et souligne l'esprit de coopération avec lequel aussi bien les différentes missions que les expériences conjointes ont été menées dans le cadre d'une étroite collaboration entre pas moins de six sondes spatiales. Cet esprit continue d'ailleurs à régner après la Rencontre avec la comète pour trouver son couronnement dans une conférence scientifique de grande envergure, qui devrait permettre au Comité de poursuivre son oeuvre et de concevoir de nouveaux projets d'intérêt mutuel pour l'avenir.

В своем описании организации и работы Межведомственной консультативной группы (IACG) д-р Р. Рейнхард объясняет, как космические агенства пришли к выводу, что сотрудничество в области планирования полетов, создания космических оппаратов и разработки экспериментов, а также развития систем информации повысило бы общую научную отдачу. Он рассказывает о работе трех рабочих групп, организованных IACG, и о пути их сотрудничества, которое способствовало осуществлению отдельных проектов и совместных экспериментов на шести космических кораблях, объединенных общей целью. Дух дружбы сохранился и на после-пролетной стадии, достигнув своего апогея на основной научной конференции, и был отражен в сообщении, что IACG будет продолжать работу и выделять проекты общего интереса на будущее.

R. ラインハルト博士はハレー彗星探査関係機関連絡協議会（IACG）の設立と仕事について説明するなかで、ミッションの立案、探査機や実験のデザイン、データ処理などについて協力しあうことが全体としての科学的な成果を増大させるのだ、ということを各宇宙機関は良く認識していたと述べている。彼はIACGが作った3つの作業グループの中で各機関が協力して行った仕事が、個々のミッションおよび6つの探査機がごく近くに集合することで可能になった相互協力実験に、いかに役立ったかについて説明している。この友好精神により、ハレー彗星遭遇後も大国際会議を開催したり、お互いに関心が持てる適切なプロジェクトについて合意するためにIACGを今後も存続させるというアナウンスがなされている。

Peaceful Cooperation in Space
The Inter-Agency Consultative Group (IACG)

by Rüdeger Reinhard,
Secretary IACG

For many reasons Halley's Comet, appearing once in a lifetime, is a very special comet. It is the brightest periodic comet; it is the only comet which has been regularly observed for more than 2000 years; and over many centuries it has, more than any other comet, stimulated artists and scientists alike. It was the study of this comet which led Edmond Halley to discover the periodicity of some comets, demonstrating that comets are members of our solar system. During the 1985/86 apparition, it was the focal point of the largest space research campaign ever, involving more than 10000 scientists and engineers in worldwide peaceful cooperation.

Five years earlier, four national and international space agencies, Intercosmos, the Japanese Institute of Space and Astronautical Science (ISAS), the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA), had decided on their individual strategies to explore Halley's Comet. Intercosmos was planning to send two spacecraft, called Vega 1 and 2, to the comet, ISAS was also planning to send two spacecraft, called Sakigake and Suisei, ESA was planning to send Giotto while NASA was planning to divert the ICE spacecraft which was already in interplanetary space, and was mounting a significant programme of space activities utilising other existing spacecraft, Space Shuttle payloads and sounding rockets.

It was soon evident to the four agencies that there was ample scope for useful collaboration before and after the launches. The fly-by distances, ranging from 30 million to 600 kilometres, the flyby dates, from 6 to 14 March 1986, and the instrumentation to be carried on the spacecraft were complementary. The agencies realised that many aspects of mission planning, spacecraft and experiment design, and data evaluation were common to all the missions, and that the overall scientific return could be increased through cooperation. They therefore met in 1981 to form the Inter-Agency Consultative Group (IACG).

The IACG had the task of coordinating, informally, all matters related to the space missions to Halley's Comet, and the observations of Halley's Comet from space, while all ground-based Halley observations were, and still are, coordinated by the International Halley Watch (IHW). The first meeting of the IACG was convened in Padua, Italy in September 1981. At this meeting numerous details of the various space missions were exchanged for the first time and the general principles of cooperation were established. Three working groups were formed in which many of the problems common to all space missions to Halley's Comet were discussed, resulting in recommendations to those responsible for the flight projects, or the allocation of specific tasks. The three Working Groups were

— The Halley Environment Working Group
— The Plasma Science Working Group
— The Spacecraft Navigation and Mission Optimisation Working Group.

Since its formation the IACG has met annually, with the task of organising the meeting, and consequently the meeting place, rotating within the four agencies. The meetings are usually chaired by a Senior Director or the Director General of the host agency. He is supported in that task by an Executive IACG Secretary, who prepares the meeting agenda in consultation with the Agencies and carries out the day-to-day work in the interim between the meetings.

With between five and ten delegation members from each agency attending the IACG meetings and adopting an informal approach which has allowed unhindered exchange of expertise a new level of Inter-Agency collaboration has been built up. Representatives of the IHW participated in all meetings, and in this way the best possible coordination of ground-based and space-borne observations was achieved. The IACG meeting agenda included reports on spacecraft and experiment design, mission planning, reports from the three Working Groups, a number of miscellaneous items of mutual interest and was usually concluded with reports by the agencies on their future space mission plans, some of which might be candidates for future cooperation.

Much of the work was carried out in the Working Groups, meeting on an average twice a year. The task of the Halley Environment Working Group was to develop and update continuously model parameters for the comet nucleus, dust, and gas environments. The project teams were provided with many data on the dust to be expected on the various spacecraft trajectories enabling them to design effective dust shields and to select optimum flyby trajectories. In particular, prediction of dust jets, regions in the cometary atmosphere with a high concentration of dust, proved extremely useful.

The close co-existence of six spacecraft in interplanetary space - a situation which had never existed before - stimulated the scientists in the Plasma Science Working Group to make simultaneous measurements during the cruise phase. Special time periods for intensive acquisition of plasma data were identified. One period was of course centred around the times of the various flybys of Halley's Comet. As the spacecraft encountered Halley's Comet one after another there were always five spacecraft outside the cometary atmosphere which could make measurements to characterise the interplanetary medium in which the comet was enbedded at the time of the encounter.

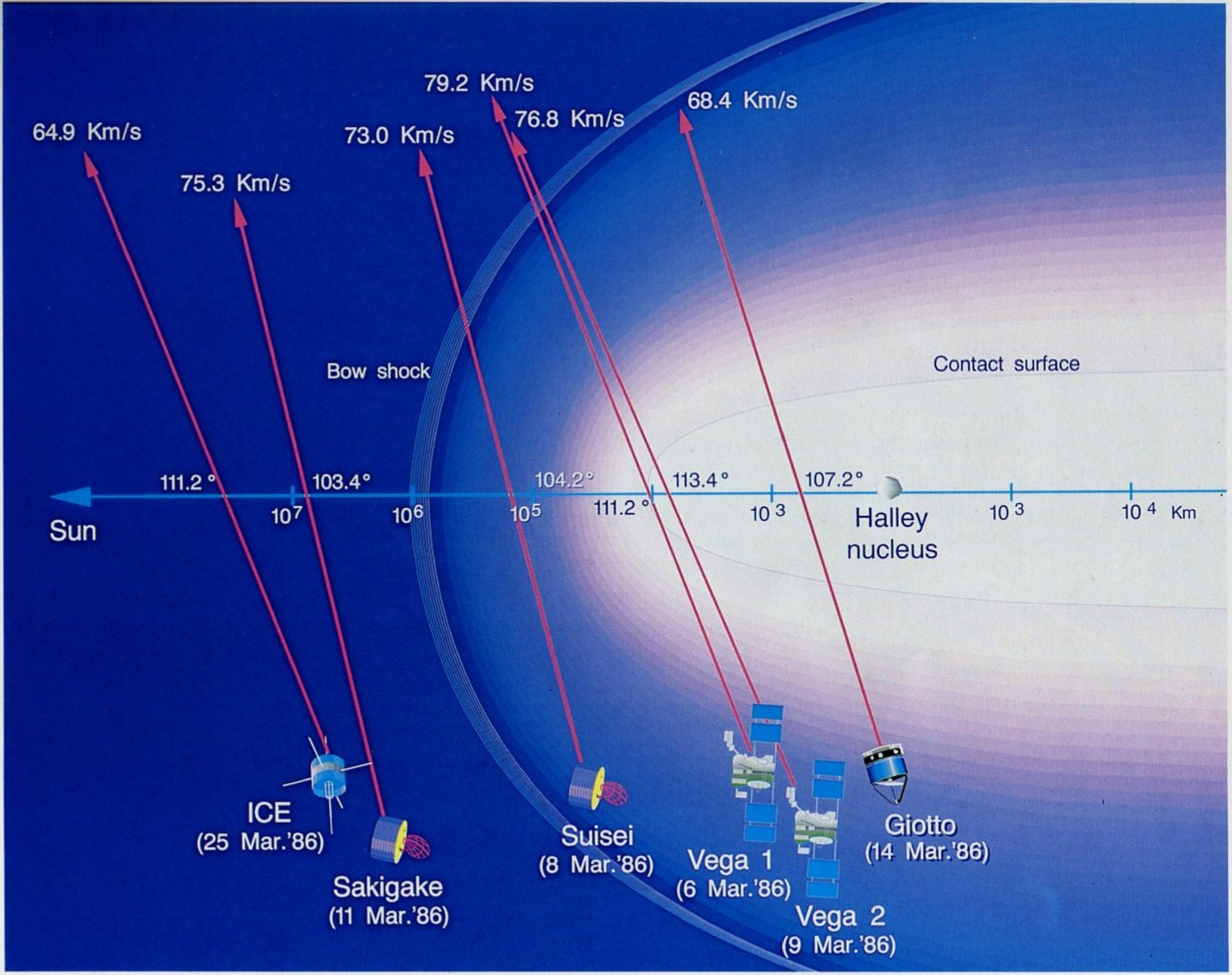
To the Spacecraft Navigation and Mission Optimisation Working Group fell the task which would have the strongest impact in targeting Giotto. The position of the nucleus is disguised by the gas and dust in the coma and cannot be observed from Earth. Furthermore, the irregular emission of large amounts of gas and dust from the heated sun-facing side of the nucleus, pushes the nucleus away from the Sun (rocket effect) in an unpredictable way and leads to a perturbation of the cometary orbit.. Before the encounters the best estimates of the position of the nucleus in the coma still had an uncertainty of about 400 km. This was more than adequate for all observations from the ground and near-Earth space and also for all encounter spacecraft with the exception of Giotto, intended to flyby the nucleus at only 600 km. Fortunately, Giotto was the last of the spacecraft to encounter the comet, and the cameras on the Vega 1 and 2 spacecraft, which had arrived earlier, having located the nucleus, could pass the information on the nucleus position to Giotto. This 'Pathfinder Concept' could not have been realised without NASA tracking the Vega spacecraft and determining very precisely their position. Although the time between acquisition and evaluation of all the data and making the last orbit correction manoeuvre for Giotto was extremely short, the pathfinder concept turned out to be successful and Giotto could be targeted with an accuracy of 40 km: ten times more accurately than would otherwise have been possible.

During the various encounters scientific data were freely exchanged to optimise the scientific return of the space missions and to put the data in their proper context during the early evaluation stage. Continuing the cooperative spirit, only two months after the encounters, first results were jointly published in the journal *Nature*, and six months after the encounters a major scientific conference on the *Exploration of Halley's Comet* was held in Heidelberg (FRG). This Symposium was attended by scientists from all the space missions and ground-based astronomers who discussed and compared their results. The formal presentations and informal discussions and exchanges of ideas at the Symposium bear witness to the enduring spirit of cooperation.

Such has been the success of the concept and practices of the IACG that agreement has been reached that the Group should stay in being, and that suitable projects of interest to all the countries involved should be identified, so that the harmony and spirit of cooperation fostered during the encounter with Halley's Comet can be nurtured still further in the interests of the peaceful exploration of space.

IACG

Inter - Agency
Consultative Group


79.2 Km/s
64.9 Km/s
73.0 Km/s
76.8 Km/s
68.4 Km/s
75.3 Km/s
Bow shock
Contact surface
111.2 °
103.4°
104.2°
113.4 °
107.2°
Sun
10⁷
10⁶
10⁵
111.2 °
10 3
Halley
nucleus
10 3
10 4
Km
ICE
(25 Mar.'86)
Sakigake
(11 Mar.'86)
Suisei
(8 Mar.'86)
Vega 1
(6 Mar.'86)
Vega 2
(9 Mar.'86)
Giotto
(14 Mar.'86)

Le concept de l'"Eclaireur'

Les observations faites au sol n'ont permis de situer la position du noyau au sein de la chevelure de la comète qu'à l'intérieur d'une certaine zone d'incertitude (grande ellipse entourant la trajectoire du noyau). Ce dernier a pu cependant être localisé par les caméras embarquées sur la sonde Vega envoyée en 'éclaireur', dont la position a ensuite été déterminée avec une grande précision (petite ellipse entourant la trajectoire de Vega) par le Réseau d'observation de l'espace lointain de la NASA. De la sorte, on a pu ajuster la trajectoire de Giotto de manière à lui faire survoler le noyau avec une incertitude beaucoup plus réduite (petite ellipse entourant la trajectoire de la comète).

Определение траектории ядра кометы

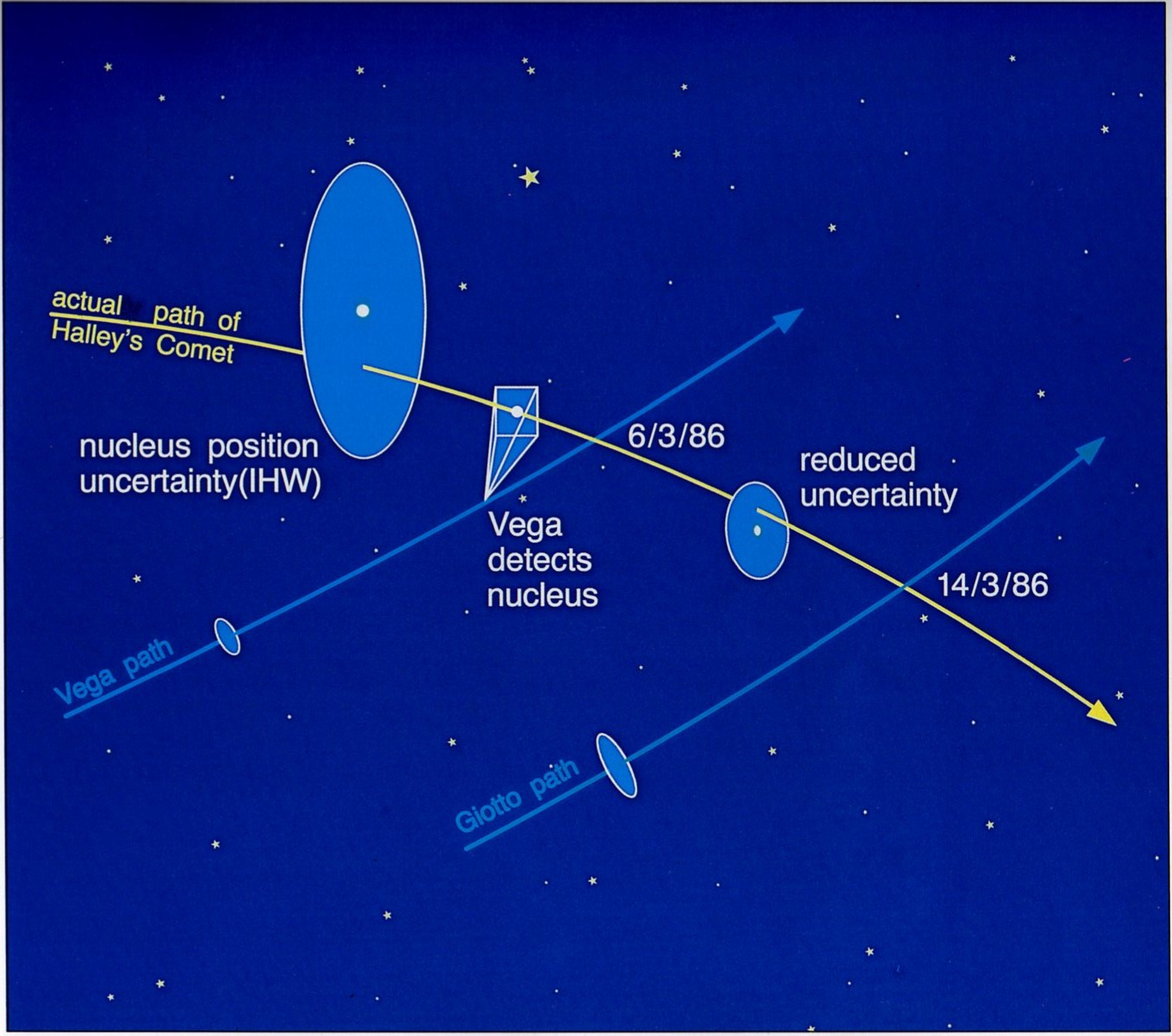
Принцип определения траектории. Тоьность, с которой было известно положение ядра внутри комы на основе только наземных наблюдений обозначена большим кружком вокруг фактиьеской траектории ядра кометы (слева направо). Телекамеры на ранее прибывших аппаратах Вега определили положение ядра, и, НАСА, используя свою сеть станций для наблюдений за объектами в далеком космосе, определило положение Веги с высокой точностью (маленький круг на траектории ВЕГИ), что позволило нацелить. Джотто на ядро с значительно меньшей ошибкой (маленький круг на траектории кометы Галлея).

パースファインダー計画

パースファインダー計画の概念。地上観測データだけから彗星コマ中での核の位置を決める時の不確定度が、彗星核の軌道（左から右へ）の囲りに大きな円で示されている。ハレーにいち早く到達したヴェガ探査機のカメラが核の位置を測定し、米国航空宇宙局が深宇宙ネットワークを使って高い精度でヴェガの位置を決めた（ヴェガ軌道に沿っての小円）。こうしてジョットは彗星核に極めて良い精度で近づいた（ハレー軌道周辺の小円）。

Pathfinder

The pathfinder concept. The uncertainty with which the position of the nucleus was known within the cometary coma from ground-based observations only is indicated by the large circle round the actual path of the comet nucleus (from left to right). The cameras on the earlier arriving Vega spacecraft located the nucleus, and NASA using its Deep Space Network determined the position of the Vega spacecraft with high precision (small circle around the Vega path), allowing Giotto to be targeted to flyby the nucleus with greatly reduced uncertainty (small circle around the Halley path).


actual path of Halley's Comet
nucleus position uncertainty(IHW)
Vega detects nucleus
6/3/86
reduced uncertainty
14/3/86
Vega path
Giotto path

L'auteur décrit brièvement la composition physique générale des comètes avant la rencontre: le noyau, constitué de glace et de poussière, dont l'origine remonte peut-être à celle du Système solaire lui-même; les glaces, qui s'évaporent à mesure que le noyau s'approche du Soleil; et enfin la chevelure et la double queue de gaz et de poussière. Grâce à la caméra de Giotto, on a pu estimer le grand axe du noyau à 15 – 16 km, et son petit axe à 8 – 10 km. Le noyau, plus sombre que prévu, est truffé de trous cratériformes, la majeure partie de la poussière et du gaz s'échappant par un petit nombre de sources. Sa température est d'environ 300 – 400 K, avec rayonnement infrarouge. On pense que sa surface est couverte d'une fine substance isolante, poreuse et réfractaire, avec une croûte de poussière recouvrant peut-être de la glace. Des observations répétées ont permis d'estimer la période de rotation à 52,9 heures. La vapeur d'eau, qui représente 80% de la production totale de gaz, constitue la molécule-mère dominante dans la chevelure. On y a décelé également de l'oxyde de carbone, de l'ammoniac et du méthane. Une découverte inattendue: parmi les nombreux ions détectés, on a constaté la nette prédominance d'ions de carbone et l'absence d'ions d'azote. Des particules de poussière, composées d'un grand nombre d'éléments, ont été détectées à 300 000 km du noyau. Le front de choc qui sépare le plasma du vent solaire et l'ionosphère de la comète a été observé à environ 1,1 million km et à 450 000 km de distance. Des ions de capture ont été observés à des distances de 10 millions et peut-être jusqu'à 30 millions km. La traversée de la surface de discontinuité a eu lieu à 4700 km avant et à 3800 km après le passage au minimum de distance de la comète, la température ionique passant ainsi de 2600 à 340 K. D'autres observations ont révélé que le nuage d'hydrogène entourant la comète s'étendait largement au delà de 10 millions km.

Д-р Рейнхард кратно изложил общую концепцию физики комет, существовавшую до пролетов кометы Галлея: ядро, состоящее из газа и пыли, образование которого возможно относится ко времени образования солнечной системы, льды, сублимирующиеся по мере приближения ядра и Солнцу, и газопылевая кома и хвост, образовавшихся при приближении к Солнцу. Снимки ТВ-камеры космического корабля ДЖОТТО позволили определить размеры ядра по большой оси - 15-16 км, по малой оси - 8-10 км. Ядро темнее, чем ожидалось, видны несколько кратероподобных образований, и большая часть пыли и газа выделяется из нескольких дискретных источников. Температура области ядра 300-400 К, обнаружено инфракрасное излучение. Предполагают, что поверхность покрыта тонким изолирующим слоем темного, пористого, тугоплавкого вещества, лед вероятно расположен под коркой пыли. Период вращения оценен по нескольким наблюдениям и равен 52,9 часа. Водяной пар является преобладающей родительской молекулой в коме кометы Галлея (80% общего выхода газа). Также найдены углекислый газ, аммиак и метан. Неожиданным было обнаружение большого числа ионов углерода и отсутствие ионов азота. Частицы пыли состоят из многих элементов и их регистрировали уже на расстоянии 300.000 км от ядра. Гиловная ударная волна между плазмой солнечного ветра и кометной ионосферой изблюдалась на расстоянии примерно 1.1. миллиона километров и 450.000 км. Захваченные ионы регистрировались на расстоянии 10 миллионов и, возможно, 30 миллионов километров. Контактная поверхность пересекалась на расстоянии 4700 км при подлете и 3800 км при удалении от кометы: поперек контактной поверхности температура ионов падала от 2600 до 340 К. Другие наблюдения позволили определить, что водородное облако вокруг кометы простирается на расстоянии более 10 миллионов километров.

ラインハルト博士は探査機とハレーとの遭遇以前における彗星の物理についての一般的な考えを概活している：核が氷とダストからなっており、起源はおそらく太陽系の形成時にまで遡るべきものであること、氷は核が太陽に近づくにつれ蒸発し、ガスやダストのコマを、そして尾を作り出すこと等である。ジョットのカメラは核の長軸は15—16km、短軸は８—10kmであることを明らかにした。核は予想されたよりも暗く、数個のクレーター状の模様が表面に見られた。放出されたダストやガスの多くは少数の離散的な源からやってくる。核付近の温度は300—400°Kでありそれによる赤外放射が検出された。表面は暗い、多孔質の、耐熱的な物質で出来た薄い熱遮蔽層でおおわれ、氷はおそらくこのダストの地殻の下にあると考えられる。いくつかの観測から、自転周期は52.9時間であると見積られた。水蒸気はハレーのコマの主要な親分子である（全ガス産出量の80%）。二酸化炭素、アンモニア、メタンもまた見出された。多くのイオンのうちで、意外だったのは大量の炭素イオンの発見と窒素イオンが見出せないことであった。ダスト粒子は広い範囲の元素からなっており、核から35万kmでも検出された。太陽風プラズマと彗星電離層とがつくり出す衝撃波面は約110万kmと45万kmで観測された。捕捉イオンは1,000万kmのところで、またおそらくは3,000万kmのところまでも観測された。接触不連続面は近づくときは、4,700kmのところで、遠ざかるときは3,800kmのところで横切られた。この不連続面を横切るとイオン温度は2,600Kから340Kに急減した。他の観測は、彗星のまわりの水素コマは1,000万kmを越えて伸びているのを明らかにした。

Scientific Highlights of the Spacecraft Encounters with Halley's Comet

by Rüdeger Reinhard,
Secretary IACG

In March 1986 a fleet of six spacecraft from four agencies encountered Halley's Comet for the first close-up investigation ever. The spacecraft differed in size, shape, mass, and scientific payload; they encountered the comet at different times and at different distances, ranging from 600 kilometres to 30 million kilometres. All encounters were successful and the complement of the scientific results - obtained by a total of 50 experiments, involving more than 100 scientific institutes and over 500 scientists from all over the world - dramatically increased our understanding of comets. Although the encounters were of necessity short due to the high relative flyby velocities - they typically lasted a day - a wealth of scientific data was collected, thorough analysis of which will take years. Nevertheless a number of major discoveries can already be clearly identified.

Before the encounters the general concept of the physics of comets was as follows. In the centre of the cometary atmosphere there is a small solid nucleus consisting of ices and dust. This nucleus is too small to be observed from Earth. Comets are thought to have been formed at the time of the genesis of the solar system, 4.6 billion years ago. Their elemental and isotopic composition may be indicative of the early solar system composition because comets spent most of their time at very large distances from the Sun in the 'Oort cloud'. Occasionally, the orbit of a comet is perturbed by a passing star, and it may be deflected into the inner solar system.

When the nucleus approaches the Sun, which in the case of Halley's Comet happens every 76 years on average, it is heated up and the ices begin to sublime. The expanding gas carries with it fine grains of dust. Both constituents, the gas and the dust, form the cometary atmosphere which can extend more than 100000 kilometres. This atmosphere or coma is bright because the dust particles in it reflect the sunlight and the gas is excited by sunlight and emits fluorescent radiation. The cometary gas is ionised by solar ultraviolet radiation, by electrons and by charge exchange with the solar wind plasma. The ions are swept in the anti-solar direction by the solar wind and form a narrow tail of cometary ions.

The dust particles which are initially emitted towards the Sun are eventually pushed back by the sunlight and also form a tail; a broad and curved dust tail. The two tails can attain lengths of many millions of kilometres and it is mostly the tails which provide the well-known spectacular appearances of many comets.

None of the spacecraft was aimed at the tail region. They were all targeted to pass the nucleus on the sunward side; the side from which all activity originates. The Giotto spacecraft passed the nucleus closest of all and the images taken by its camera clearly revealed the cometary nucleus. It was not spherical as had been anticipated and it was larger than expected. Some scientists would not have been surprised to see multiple nuclei. The shape of the nucleus resembles that of a peanut or an elongated potato; its major axis is 15-16 kilometres, its minor axis 8-10 kilometres. Also the Halley Comet nucleus was darker than expected, with a surface reflectivity (albedo) of only a few percent, comparable to the darkest objects in the Solar System. Close-up images of the nucleus revealed several crater-like features of about one kilometre diameter. It is not clear what caused them. Two major bright dust jets emanate from the sunward side of the nucleus. Dust jets are regions in the cometary coma in which the dust density is enhanced making the jets appear brighter than the ambient coma. The maximum brightness is close to the nucleus where the dust density is highest, because there the dust particles have not yet attained their full velocity. Apparently almost all of the emitted dust and gas comes from only a few discrete sources.

Unfortunately, no Giotto images are available from the outward bound pass. This loss is compensated for by the images taken by the cameras on the Vega spacecraft; they obtained images on the approach and outward bound passes, thus providing views of the nucleus from two different sides. With two spacecraft passing the nucleus at an interval of three days, it was possible to determine the rotation period of the Halley nucleus and to construct a three-dimensional model of it. All the images (Giotto and Vega) have a fuzzy appearance because of the dust in the coma. Therefore, the exact shape cannot be determined and the dimensions have still an uncertainty of about one kilometre.

One of the most important new results is the detection of infrared radiation from the nucleus region by the infrared spectrometer on Vega 1. The temperature of the nucleus region was found to be 300-400K, much greater than the sublimation temperature of water ice (180-200K). The conclusion is that the surface of the nucleus is covered by a thin insulating layer of dark, porous, refractory substance. There can be ice at a temperature of 200K below this crust of dust. The thickness of this crust of dust is not known. The conclusion that most of the surface of the nucleus must be covered by dust is consistent with the observed low albedo.

Perhaps the most accurate determination of the rotation period of the Halley nucleus comes from the observations of the UV camera on board Suisei. This camera observed the size and brightness of the hydrogen cloud, or corona, surrounding the nucleus, in the ultraviolet, and found a regular brightness variation with a period of 52.9 hours. This brightness variation is attributed to a nucleus which regularly exposes a more active hemisphere to the Sun as it slowly rotates.

Measurements of the elemental and isotopic composition of the nucleus are just as important as obtaining images. Usually one has to land on the surface of a body to determine its composition, but comets offer a unique opportunity. Due to the outgassing of comets it is, to some extent, possible to determine the nucleus composition by measuring the composition of the dust and gas in the coma. The composition of the dust particles does not change as they leave the nucleus, but unfortunately the composition of the gas changes with distance from the nucleus in complex chains of chemical reactions including ion-molecule reactions. The species at the beginning of these chains are the 'parent molecules'; those unaltered molecules of which the nucleus is made. Some parent molecules can be observed directly, even at larger distances from the nucleus. Parent molecules with short lifetimes can in some cases be deduced when modelling the chains of chemical reactions. By measuring the density and outflow velocity of the gases and the dust in the coma the amount of material that leaves the nucleus can be determined. Estimates made before the encounters suggested that the production rates were several tons of gas and dust per second during the flybys; this would mean that a layer of one metre depth is removed from the nucleus on each apparition.

The Vega and Giotto spacecraft carried dust and gas mass spectrometers and several other instruments for measurements of the gas and dust fluxes and composition. As expected, water vapour was the dominant parent molecule in the Halley Comet coma. At the time of the Giotto flyby the total gas production rate was 6.9×10^{29} molecules a second of which 80% were water molecules. The water vapour production amounts to 15 tons a second. Carbon dioxide (CO_2), ammonia (NH_3) and methane (CH_4) were also found. Together they contribute about 10% or more of the parent molecules. The remaining parent molecules are probably some minor species which cannot be easily identified in the spectra.

The gas escape velocity was 900 ± 200 metres a second which agrees well with the outflow velocity of 1000 metres a second found for the ions close to the nucleus. A large number of ionic species could already be identified, among them hydronium (H_3O^+), water (H_2O^+), hydroxyl (OH^+), carbon (C^+), methylidine (CH^+), oxygen (O^+), carbon monoxide (CO^+), sodium (Na^+), sulphur (S^+), iron (Fe^+). Many ions had already been detected earlier by ground-based observations, but the variation of their abundance, temperature and velocity with distance from the nucleus were measured for the first time during the flybys. Quite unexpected was the large number of carbon ions and, on the other hand, a lack of nitrogen ions. The large C^+ abundance could be due to an unexpected source of atomic carbon which could be released from the nuclear surface or from the dust grains in the coma.

The dust particles in the coma of Halleys Comet are composed of a large number of elements , and the spectra of individual dust grains display wide variations. Some spectra are dominated by the light volatile elements hydrogen, carbon, nitrogen and oxygen, other dust particles mostly consist of magnesium, silicon, iron. The average chemical composition of Halley's dust is close to that of C1 chondrites (a carbon-rich stony meteorite) with carbon enriched by a factor of 8. The present status of data evaluation does not yet allow us to decide on elaborate experimental dust models or special formation processes of organic material.

Dust particle impacts were detected out to a distance of 300000 kilometres from the nucleus, slightly further than was expected. Dust particles as small as 10^{-17} grammes and as large as one gramme were detected, the latter causing a severe disturbance as it impacted on the Giotto spacecraft. The total dust production rate was 10 tons a second during the Vega 1 flyby, 5 tons a second during the Vega 2 flyby and 3 tons a second during the Giotto flyby. This activity variation is typical for Halley's Comet and is, to some extent, explained by the rotation of the nucleus. When approaching the nucleus the dust fluxes should increase quadratically if the dust emission were spherically symmetrical. There are dramatic deviations from that simple law, and the sudden flux increases observed close to the nucleus confirm the existence of dust jets seen on the images.

The interaction between the solar wind plasma and the cometary ionosphere can be characterised by two distinct boundaries, the bow shock and the contact surface. Outside the bow shock, far away from the nucleus, is the undisturbed supersonic solar wind. Inside the contact surface, close to the nucleus, there are only cometary ions. In between these two boundaries is a mixture of cometary and subsonic solar wind ions. Some cometary neutral particles can travel large distances from the nucleus before they are ionised and picked up by the solar wind ('pick-up ions'). Such pick-up ions were observed by detectors on board the Vega and Giotto spacecraft out to distances of 10 million kilometres and possibly, by the International Cometary Explorer (ICE), even at distances of 30 million kilometres.

The beam of pick-up ions in the solar wind excites low-frequency Alfvén waves due to the ion-cyclotron instability. These waves were detected by magnetometers on board Vega and Giotto at several million kilometres from the nucleus. Higher frequency waves, due to plasma instabilities associated with the pick-up of cometary ions by the solar wind, were observed out to 10 million kilometres by the plasma wave experiment on Sakigake and out to 30 million kilometres by the plasma wave experiment on ICE.

Four spacecraft observed bow shock crossings, Vega 1 and 2 and Giotto at a distance of approximately 1.1 million kilometres during approach, and Suisei, passing the nucleus closer to the Sun, at a distance of 450000 kilometres. The continuing solar wind loading by heavy cometary ions behind the shock results in a gradual deceleration of the plasma flow and a magnetic field build-up. Suisei observed a minimum flow velocity of approximately 50 kilometres a second at 150000 kilometres from the nucleus, while the Vega spacecraft passing the nucleus much closer observed almost zero velocity at the subsolar point (outside the bow shock normally 400 kilometres a second).

The Giotto magnetometer observed peak magnetic fields of 57 nT during approach, and 65 nT when outward bound, while the magnetometers on board the two Vega spacecraft observed 75 nT and 80 nT at their closest approach (outside the bow shock normally 5-8 nT).

Only Giotto passed the nucleus close enough to detect the contact surface; it was crossed at 4700 kilometres from the nucleus during approach and at 3800 kilometres when outward bound. The contact surface was identified by a sharp transition between strong fields outside (magnetic pile-up region) and essentially zero field inside (magnetic 'cavity'). Outside the contact surface a layer of stagnant cometary plasma was found; inside the cold cometary ions flowed smoothly outward at a velocity of approximately one kilometre a second. Across the contact surface the ion temperature dropped from 2600K to as low as 340K. The location of the contact surface should be determined by a pressure equilibrium between the magnetic pressure or solar wind ram pressure outside and the thermal pressure of the cometary ionosphere inside. Using the observed parameters in the equations, however, gives a distance which is much smaller than observed. Invoking the frictional force between the stagnating cometary ions and the neutrals in the region outside the contact surface leads to satisfactory agreement with the observations.

The in-situ measurements made by Giotto, Vega 1, Vega 2, Suisei, Sakigake and ICE were complemented by a large number of remote observations. They were made at visual wavelengths from the ground and from the Solar Maximum Mission (SMM) in Earth orbit, and at ultraviolet wavelengths from the International Ultraviolet Explorer (IUE), the Dynamic Explorer (DE1), the Pioneer Venus Orbiter (PVO), and during four rocket flights. UV observations are not possible from the Earth due to atmospheric absorption; they are important because the cloud of hydrogen atoms around comets (Lyman-α emission at 1216 Å) and the temporal behaviour of some primary constituents of the gaseous coma can only be observed in the UV. It was found that the hydrogen cloud around Halley's Comet at the time of perihelion extended well over 10 million kilometres. The gas production rates and activity variation derived from the data agreed well with those obtained by the flyby spacecraft. Column abundances of a large number of species were provided for comparison with the in-situ measurements by Vega and Giotto.

More than 1000 professional astronomers in 51 countries and almost 1200 amateur astronomers, some of them using professional equipment, in 54 countries provided a very large number of ground-based observations of Halley's Comet, covering the period from its recovery on 16 October 1982 until the present. Some SMM images are available from the few weeks around perihelion when Halley's Comet was in angular proximity to the Sun and no observations could be made from the Earth. The most important contribution of the International Halley Watch (IHW) will be to provide as complete as possible a record of the 1982-1990 Halley apparition in different wavelengths and with sufficient temporal resolution. The work of the IHW is organised in eight observing nets: Astrometry, Infrared Spectroscopy and Radiometry, Large-Scale Phenomena, Near-Nucleus Studies, Photometry and Polarimetry, Radio Studies, Spectroscopy and Spectrophotometry, and Meteor Streams Studies. The observations cover the Halley dust and ion tails; those regions which were unexplored by the flyby spacecraft. They include the observations of dust jets from the ground which complement the observations of dust jets made in-situ by the cameras and dust impact detectors. In addition the observations determine the orbit of Halley's Comet through precise astrometric observations needed for spacecraft navigation, and they provide insight into Halley's long-term activity variations. Questions, such as 'how long lived are the discrete dust sources on the nucleus?', are fundamental for our understanding of the nucleus and can only be answered by observations over a long period of time, that is by ground-based observations. The necessity for having both ground-based and in-situ observations was illustrated in the determination of the nucleus albedo. Only by combining the measured brightness (product of albedo and size) at recovery and the nucleus size, as observed by the flyby spacecraft, was it possible to determine the nucleus albedo.

The cooperation between the flight projects and the ground-based astronomers has brought together the largest number of scientists ever to combine efforts in a single astronomical project or study.

Temps fort

La comète de Halley vue par le Grand Prisme Objectif de 40 cm de diamètre de l'ESO à La Silla, Chili, le 1er mars 1986. Cette image fausse couleur est établie à partir de trois plaques photographiques noir & blanc à émulsions et temps de pose différents: émulsion IIa-O sensible au bleu (7 mn), émulsion IIa-D sensible au vert avec filtre GG495 (7 mn) et émulsion 098-04 sensible au rouge avec filtre RG630 (20 mn). On distingue parfaitement la queue de gaz (bleuté) et la queue de poussière (rougeâtre). Le champ de vue est d'environ 1° (ou 3,3 millions km).

Выдающиеся научные результаты

Комета Галлея 1 марта 1986 г. Изображение получено в Европейской Южной Обсерватории в Ла Силла, Чили с помощью 40-цм двойного астрографа. Цветная фотография получена совмещением трех черно-белых фотоплатинок, используя различные эмульсии и времена экспозиции: эмульсия IIa-O чувствительная к синему (7 мин), эмульсия IIa-D с фильтром GG 495 чувствительная к зеленому (7 мин) и эмульсия 098.04 с фильтром RG 630 чувствительная к красному (20 мин). На фотографии четко видны синеватые хвосты газа и красноватые хвосты пыли. Размер кадра примерно 1°, или 3,3 миллиона километров.

科学的成果

1986年3月1日のハレー彗星。この像はチリのラシラにあるヨーロッパ南天天文台の40cmダブルアストログラフで撮られた。カラー写真はそれぞれ異なった乳剤と露出時間でとられた3枚の黒白写真から合成されたものである（フィルターCG495を通して、青に感ずるO-乳剤を使ってとられたもの、同緑に感ずるD-乳剤を使ってとられたもの（ともに7分間の露出)、フィルターRG630を使って赤に感ずる098.04乳剤を使ってとられたもの（20分の露出）の3枚)。写真は明瞭に青いガスの尾と赤いダストの尾とを明らかにしている。フレームの大きさは約1°、すなわち330万kmである。

Scientific Highlights

Halley's Comet on 1 March 1986. The image was obtained with the 40 cm Double Astrograph of the European Southern Observatory in La Silla, Chile. The colour photograph is a composite of three black and white photographic plates using different emulsions and exposure times: blue sensitive IIa - O emulsion (7 min), green sensitive IIa - D emulsion behind a GG 495 filter (7 min) and red sensitive 098-04 emulsion behind an RG 630 filter (20 min). The picture clearly shows the bluish gas tails and the reddish dust tails. The size of the frame is about 1°, or 3.3 million km.

Temps fort

Images fausse couleur prises par la caméra grand champ à dispositif à transfert de charge de l'ESO à La Silla, montrant la présence de CO^+ dans la comète de Halley les 13, 14, 18, 19 et 20 mars 1986. On a utilisé un filtre interférentiel spécial de 7 nm de bande passante centré sur 426 nm, là où se produit l'émission spectrale des ions CO^+, qui sont repoussés par le vent solaire vers la comète. Ces ions sont vraisemblablement issus de l'anhydride carbonique (CO_2) présent dans le noyau sous forme de glace sèche. La succession des images montre des changements rapides intervenus dans la queue CO^+.

Выдающиеся научные результаты

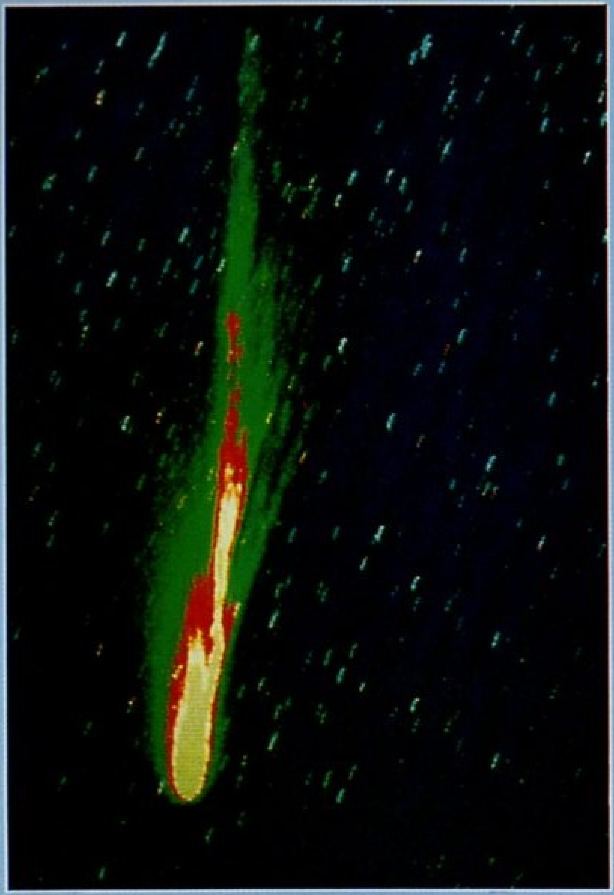
CO^+ кометы Галлея 13, 14, 18, 19 и 20 марта 1986 (слева направо). Эти изображения в условных цветах были получены с помощью широкоугольной ТВ-камеры на ПЗС Европейской Южной Обсерватории в Ла Силла, Чили, с помощью специального интерференционного фильтра. Фильтр имеет полосу пропускания 7 нм с центром вблизи 426 нм, где имеет место спектральное излучение CO^+ радикала. Изображения покрывают распределение этих ионов по комете, по мере того как они „выталкиваются" солнечным ветром. Вероятно, источником их происхождения является углекислый газ (CO_2), который присутствует в качестве сухого льда в ядре. На серии снимков видно, как быстро происходят изменения в CO^+ хвосте.

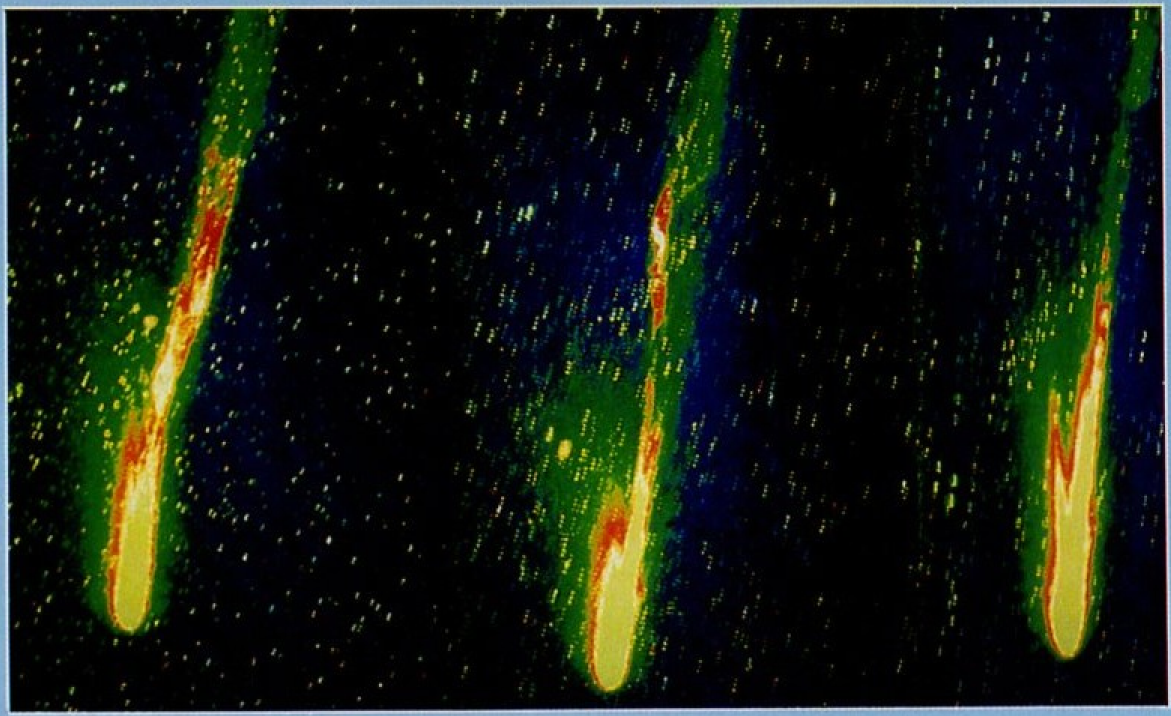
科学的成果

1986年3月13、14、18、19日（左から右）のハレー彗星のCO^+。これらの擬似カラーはチリのラシラにあるヨーロッパ南天天文台において、特別の干渉フィルターを使った広角CCDカメラにより撮られた。このフィルターは426nmに中心をもつバント幅7nmのフィルターでCO^+基の発光線をその域内におさめる。この像は彗星中の同イオンが太陽風により押し流されてゆく様子を示している。これらのイオンが核中にドライアイスとして存在している二酸化炭素（CO_2）をその起源としていることは考えられることである。一連の画像はCO^+の尾の急速な変化の様を示している。

Scientific Highlights

CO^+ tail of Halley's Comet on 13, 14, 18, 19, and 20 March 1986 (from left to right). These false colour images were obtained with the Wide Field CCD camera of the European Southern Observatory in La Silla, Chile, using a special interference filter. The filter has a passband of 7 nm and is centred near 426 nm, where spectral emission from the CO^+ radical occurs. The images show the distribution of these ions in the comet as they are pushed away by the solar wind. It is likely that they originate from carbon dioxide (CO_2) which is present as dry ice in the nucleus. The series of images displays rapid changes in the CO^+ tail.





Temps fort

La comète de Halley vue par le télescope de Schmidt de 1 m de diamètre de l'ESO à La Silla (Chili) les 8, 9 et 10 mars 1986 (pose de 30 mn avec filtre bleu). Le 8 mars, la principale queue ionique présente une structure en torsade avec de nombreux serpentins étroits sur le versant sud; on distingue également pas moins de sept larges queues de poussière diffuse sur le versant opposé. Le 9, la queue ionique devient plus désordonnée, les tortillons ayant une amplitude accrue; par contre les serpentins sont moins nombreux. Le jour suivant, une partie de la queue ionique s'est détachée, phénomène appelé 'événement de rupture', qui se produit lorsqu'une limite de secteur interplanétaire poussée par le vent solaire dépasse la comète.

Выдающиеся научные результаты

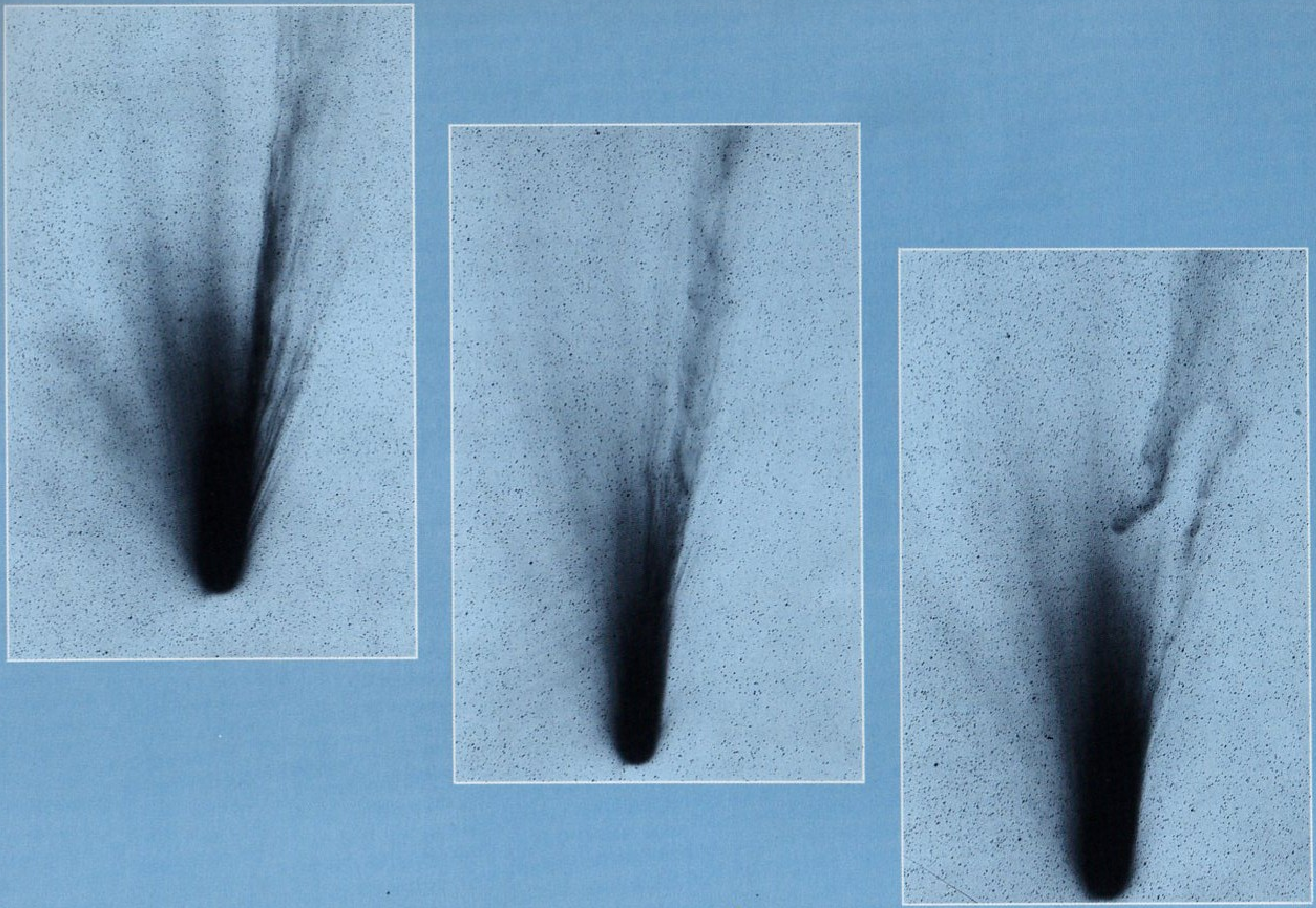
Комета Галлея 8, 9 и 10 марта 1986 (слева направо). Эта серия 30-мин синих экспозиции получена с помощью 1-м телескопа Шмидта в Европейской Южной Обсерватории в Ла Силла, Чили. На снимке, сделанном 8 марта, основной ионный хвост имеет волнистую структуру и на южной стороне видны многочисленные узкие стримеры. На противоположной стороне также видны, по крайней мере, семь широких диффузных пылевых хвостов. На снимке 9 марта ионный хвост выглядел более беспорядочно, амплитуда его завитков увеличилась. Видны так же несколько стримеров. На снимке 10 марта часть ионного хвоста начала отрываться. Это явление называется явлением отрыва. Это случается, когда комета проходит через границу сектора межпланетного магнитного поля.

科学的成果

1986年3月8、9、10日（左から右）のハレー彗星。この一連の写真（それぞれ30分の露出時間で青に力点がおかれている）はチリのラシラのヨーロッパ南天天文台の1mシュミット・カメラにより撮影された。最初の日のものでは、主要なイオンの尾は波うった構造をしており、南側には多くの狭い流線（streamers）がある。反対の側には少くとも7個の幅広い、うすいダストの尾がみてとれる。3月9日にはイオンの尾はもっと乱れ、波うちの幅も増大した。流線の数も減少している。翌日にはイオンの尾の一部がはがれている。この現象は尾の切断と呼ばれている。これは、太陽風によって運ばれる惑星間のセクター界面が彗星を横切るときに生ずる。

Scientific Highlights

Halley's Comet on 8, 9, and 10 March 1986 (from left to right). This series of three 30 min blue exposures was obtained with the 1 m Schmidt telescope of the European Southern Observatory in La Silla, Chile. On the first date, the main ion tail has a wiggly structure and there are many narrow streamers on the southern side. At least seven broad, diffuse dust tails are also visible on the opposite side. On 9 March, the ion tail is more disordered; the amplitude of the wiggles has increased. There are also fewer streamers. The next day, a part of the ion tail has become detached. This phenomenon is called a disconnection event. It occurs when an interplanetary sector boundary carried by the solar wind passes the comet.



Temps fort

Courbe de lumière de la comète de Halley pendant la saison 1985–86, montrant les variations de brillance ou de magnitude en fonction du temps (en haut) et de la distance au Soleil (échelle horizontale en bas). On a suprimé l'effet des variations de magnitude dû à la variation de la distance géocentrique Δ en portant, en ordonnée, $m_1 - 5 \log \Delta$, où m_1 est la magnitude observée; toutes les observations sont ainsi normalisées sur $\Delta = 1$ unité astronomique. Si l'activité de la comète était faible ou nulle, la brillance augmenterait de façon quadratique à l'approche du Soleil. Cependant, comme l'atmosphère de la comète augmente en volume et en brillance à mesure qu'on s'approche du Soleil, l'augmentation est encore beaucoup plus rapide. Les traits continus de la période précédant le périhélie correspondent à un accroissement à la puissance 4,5. L'accroissement entre 3 et 1,8 UA est même plus net, indiquant un important surcroît d'activité causé sans doute par la sublimation de la glace qui commence à 2,8 UA. La dispersion des données traduit non seulement les incertitudes rencontrées pour la détermination de la magnitude mais aussi les variations réelles de l'activité à court terme.

Выдающиеся научные результаты

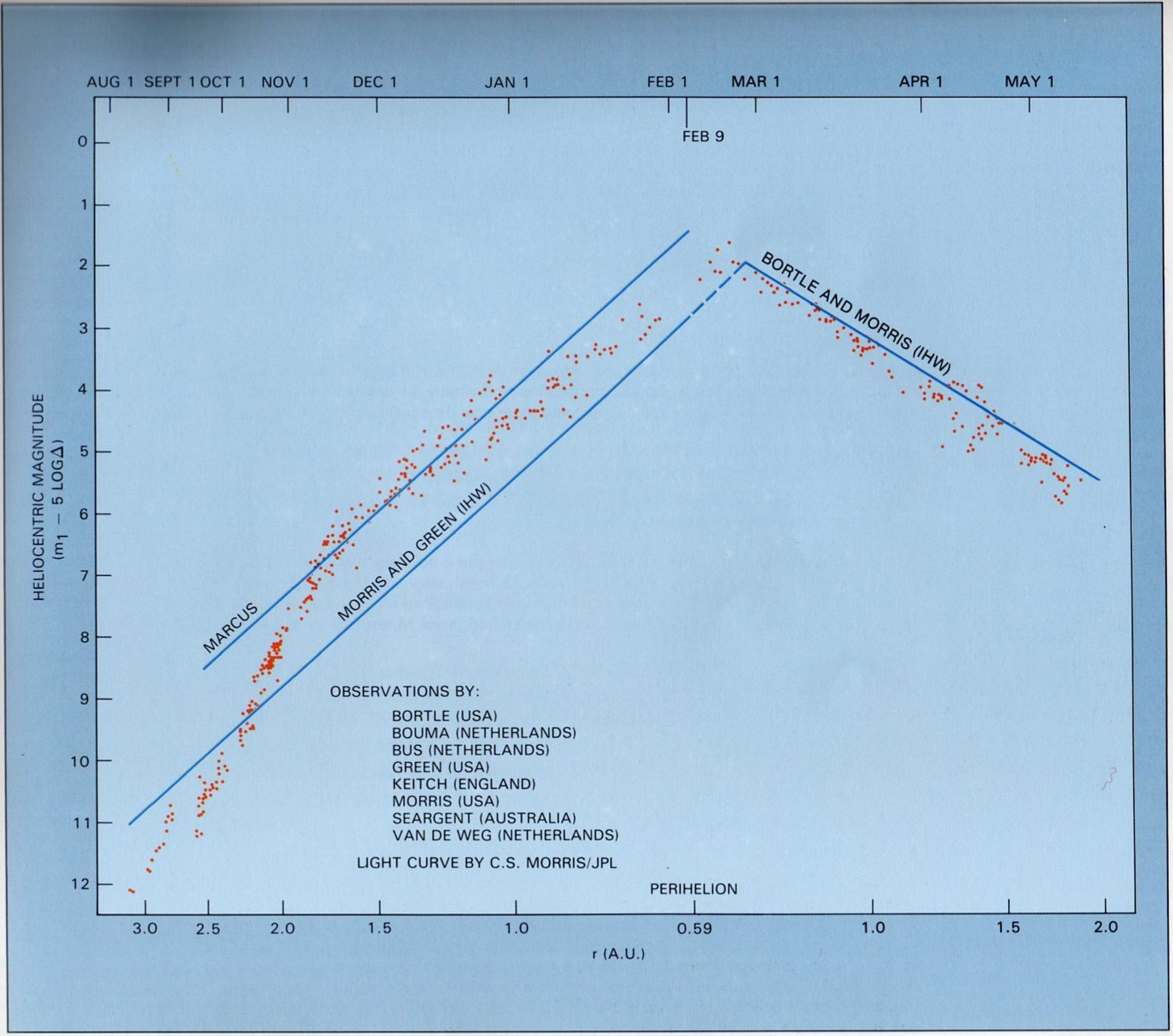
Кривая блеска кометы Галлея во время её появления в 1985/86 показывает изменение яркости или звездной величины во времени (верх) или с изменением гелиоцентрического расстояния (низ, горизонтальная шкала). Эффект изменения звездной величины с геоцентрическим расстоянием Δ был устранен, откладывая по вертикальной оси m_1-5log Δ, где m есть наблюдаемая звездная величина; таким образом все наблюдания были нормализованы к $\Delta = 1$ а.е. Если комета была бы неактивна, яркость увеличилась бы пропорционально квадрату расстояния до Солнца. Однако, размер атмосферы кометы и её яркость увеличивались при приближении к Солнцу более резко. Сплошкые линии, соответствующие области до перигелия, показывают экспоненциальное увеличение яркости с показателем 4, 5. Рост яркости в области 3-1,8 а.е. ещё круче, что указывает на развитие основной активности, вероятно вызванной сублимацией водного льда, которая начинается в области 2,8 а.е. Разброс точек данных отражает неопределенность нахождения звездной величины, а также связан с коротковременными изменениями активности.

科学的成果

1985/1986年のハレー彗星回帰における光度曲線。時間（上の横スケール）と、太陽からの距離（下の横スケール）に関する輝度あるいは等級の変化を示す。地球からの距離（△）による等級変化の効果は垂直軸方向にm_1 —5ℓog △をプロットすることにより除かれてしまっている（m_1は観測された等級）：こうした手続きによりすべての観測は△＝1AUに正規化されたものとなっている。もし彗星が不活発なものであると、輝度は太陽に向って（距離の）逆２乗で増大するであろう。しかし、彗星をとりまく大気の大きさも輝度も太陽に向って増大するので、それはもっと強い上昇を示すことになる。近日点通過前の実線は4.5という冪指数での増大に相当している。3～1.8AUの内での増加はさらに強いものでさえあり、彗星の主要活動が始まった事を示している。それはおそらく水の氷の蒸発が2.8AUにおいて始まったことによりもたらされたものであろう。データ点のばらつきは、等級決定の際の不確定さと彗星活動の短周期変動とから生じている。

Scientific Highlights

Light curve of Halley's Comet during the 1985/86 apparition, showing the variation of the brightness or magnitude with time (top) or heliocentric distance (bottom horizontal scale). The effect of the magnitude variation due to a varying geocentric distance Δ has been removed by plotting $m_1 - 5 \log \Delta$ on the vertical axis, where m_1 is the observed magnitude; in this way all observations are normalised to $\Delta = 1$AU. If the comet would be inactive the brightness would increase quadratically towards the Sun. However, as the cometary atmosphere grows in size and brightness towards the Sun, the increase is much steeper. The pre-perihelion solid lines correspond to an increase with the exponent of 4.5. The increase between 3 and 1.8 AU is even steeper indicating a major activity onset, presumably caused by the sublimation of water ice which starts at 2.8 AU. The scatter in the data points reflects uncertainties in the magnitude determination and also real short-term activity variations.


AUG 1
SEPT 1
OCT 1
NOV 1
DEC 1
JAN 1
FEB 1
FEB 9
MAR 1
APR 1
MAY 1
HELIOCENTRIC MAGNITUDE
(m$_1$ − 5 LOGΔ)
0
1
2
3
4
5
6
7
8
9
10
11
12
MARCUS
MORRIS AND GREEN (IHW)
BORTLE AND MORRIS (IHW)
OBSERVATIONS BY:
BORTLE (USA)
BOUMA (NETHERLANDS)
BUS (NETHERLANDS)
GREEN (USA)
KEITCH (ENGLAND)
MORRIS (USA)
SEARGENT (AUSTRALIA)
VAN DE WEG (NETHERLANDS)
LIGHT CURVE BY C.S. MORRIS/JPL
PERIHELION
3.0
2.5
2.0
1.5
1.0
0.59
1.0
1.5
2.0
r (A.U.)

Temps fort

La comète de Halley vue par un objectif MD Rokker 1:1,7 / 50 mm le 21 mars 1986 (pose de 70 mn, film Perutz 100 ASA). La position de la comète dans le ciel était alors proche de la Voie Lactée, dans la constellation du Sagittaire. On distingue nettement la forme longue et droite de la queue ionique, mais la faible luminosité de ses contours se noie dans les nuages brillants de la Voie Lactée.

Вадающився научные результаты

Комета Галлея 21 марта, 1986. Изображение получено с помощью объектива MD Rokker 1:1,7/50 мм. Время экспозиции 70 мин на пленке Perutz 100 ASA. В этот день комета располагалась вблизи Млечного пути в созвездии Стрелец. Ясно виден длинный прямой ионный хвост, но слабый свет от наиболее удаленных от центра областей маскируется фоном сияния ярких облаков Млечного пути.

科学的成果

1986年3月21日のハレー彗星。この像はMD Rokker 1：1.7/50㎜レンズにより撮られた。露出時間は70分でPerutz 100ASAフィルムが使われた。この日には彗星は天の川の近く射手座の中に位置している。長いまっすぐなイオンの尾がのびているのがみてとれるが、その一番外側から出ている淡い光は天の川の明るい雲の輝やきの中に埋没している。

Scientific Highlights

Halley's Comet on 21 March 1986. The image was obtained with an MD Rokkor 1: 1.7 / 50mm lens. The exposure time was 70 min on Perutz 100 ASA film. On this date the comet was situated near the Milky Way band in the constellation Sagittarius. The long straight ion tail is clearly visible, but the faint light from its outermost parts is lost in the glow of the bright clouds in the Milky Way.

Acknowledgements

The IACG thanks all Principal Investigators on behalf of their teams:
G. Avanesov, H. Balsiger, S. Bame, J.-L. Bertaux, M. Combes, P. Cruvellier, P. Edenhofer, M. Gogoshev, R. Grard, K.I. Gringauz, D. Hovestadt, R. Hynds, A.D. Johnstone, E. Kaneda, H.U. Keller, E. Keppler, J. Kissel, S. Klimov, D. Krankowsky, V. Krasnopolsky, A.C. Levasseur-Regourd, E. Mazets, J.A.M. McDonnell, S. McKenna-Lawlor, T. Mukai, F.M. Neubauer, K.W. Ogilvie, H. Oya, K. Oyama, H. Rème, W. Riedler, R.Z. Sagdeev, T. Saito, F.L. Scarf, J. Simpson, E.J. Smith, A. Somogyi, J.-L. Steinberg, L. Szabo, O. Vaisberg.

The Editor and Scientific Adviser wish to thank the following people who have helped in the preparation of the book, or by providing the illustrations:

H. Balsiger, K. Barbance, P.K. Berkhout, R.-M. Bonnet, H. Debehogne, J.F. Delsman, B.I. Edelson, R. Farquhar, P.D. Feldman, B. Gelly, K. Gringauz, H.T.D. Guyenne, B. Haasnoot, R.Häfner, A.D. Johnstone, J.F. Jordan, E. Kaneda, H.U. Keller, J. Kissel, B. Kunashev, A. Langenhoff, V. Manno, P. Monderen, T. Mukai, F. Neubauer, R. Newburn, M. Oda, H. Oya, H. Pedersen, G. Pizarro, O. Pizarro, J. Rahe, R. Ruffini, R.Z. Sagdeev, J.N. Scheltens, H.-E. Schuster, R. Schwenn, M. Shimizu, K. Szegö, R. Vio, W.A. Versteeg, H.F. Wapstra, R.M. West, K. Wilhelm, B. Wilken, A.N. Zaitzev.

and our thanks to the secretaries who typed the texts, Wendy Collins, Olga Melita and Linda Mosley.